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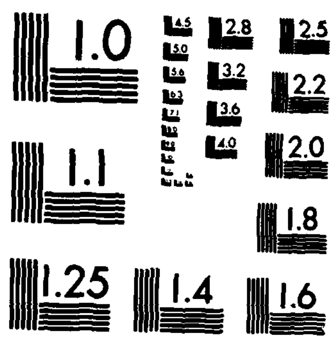

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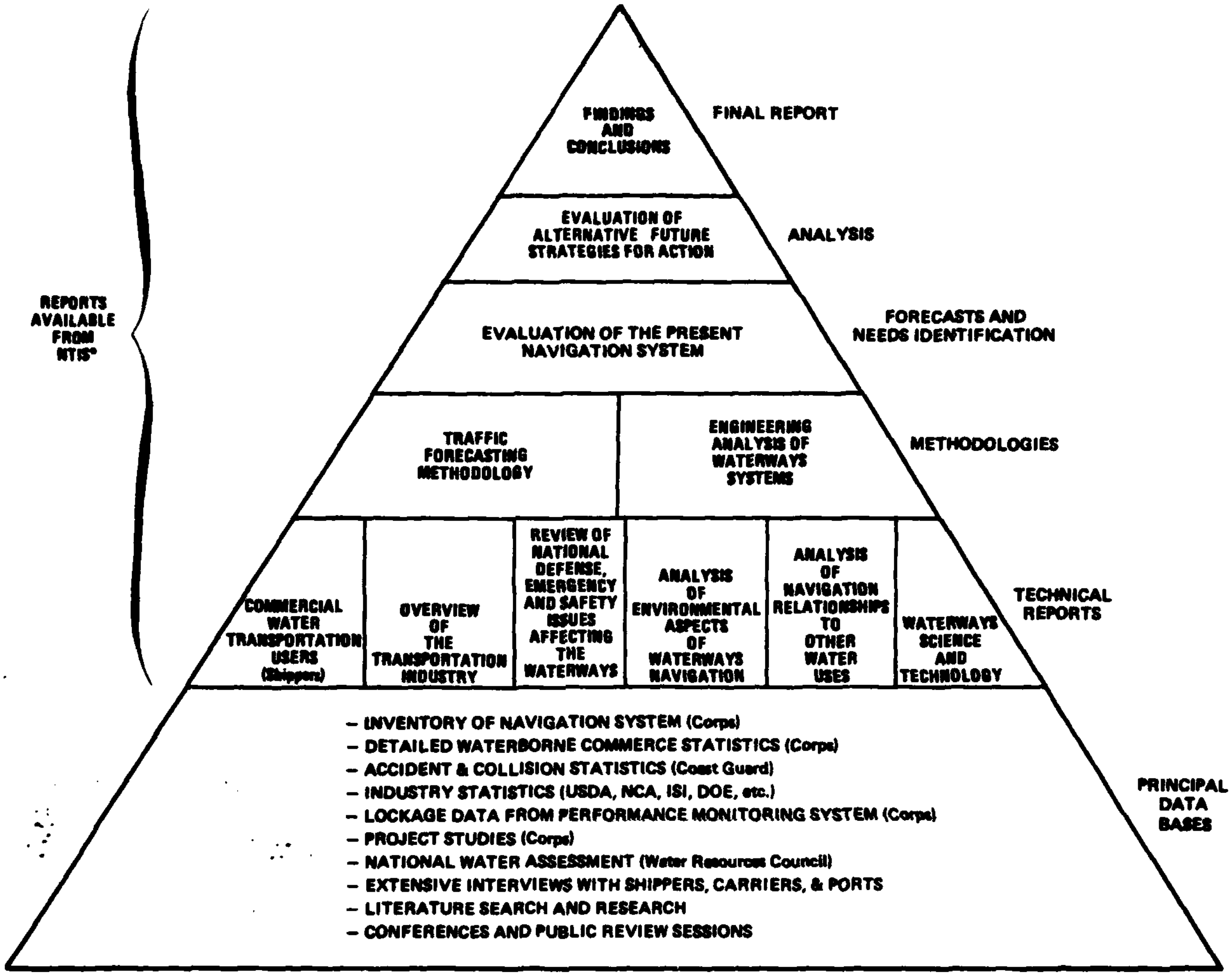

NATIONAL WATERWAYS STUDY

FINDINGS AND CONCLUSIONS

From Contractor Study Effort

(Final Report)

Prepared for the

U.S. ARMY CORPS OF ENGINEERS

By
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in association with
Data Resources, Inc.,
Louis Berger & Associates, Inc.

September, 1981

This is a deliverable under Contract DACW 72-79-C-0003. It represents the output to satisfy the requirements for the deliverable in the Statement of Work. This report constitutes the single requirement of this Project Element, completed by A. T. Kearney, Inc. and its primary subcontractors, Data Resources, Inc. and Louis Berger and Associates, Inc. The primary technical work on this report was the responsibility of A. T. Kearney, Inc. This document supercedes all working papers. This report is the sole official deliverable available for use under this Project Element.

THIS REPORT IS PART OF THE NATIONAL WATERWAYS STUDY AUTHORIZED BY CONGRESS IN SECTION 158 OF THE WATER RESOURCES DEVELOPMENT ACT OF 1976 (PUBLIC LAW 94-587). THE STUDY WAS CONDUCTED BY THE US ARMY ENGINEER INSTITUTE FOR WATER RESOURCES FOR THE CHIEF OF ENGINEERS ACTING FOR THE SECRETARY OF THE ARMY.

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The purpose of the contractor effort on the National Waterways Study has been to develop and analyze alternative strategies for the management of the nation's waterways through the year 2000. This report presents the major findings of the study's technical research (contained in ten separate reports), summarizes conclusions drawn from that research, and presents evaluations of four alternative strategies for future management of the waterways. Under the terms of the contract, this document contains no recommendations. Its purpose is to provide the analytical basis for policy recommendations by the Secretary of the Army and to support the formulation of national waterways policy by Congress.

PREFACE

This report is one of eleven technical reports provided to the U.S. Army Corps of Engineers in support of the National Waterways Study by A. T. Kearney, Inc. and its subcontractors. This report summarizes all significant findings and conclusions from the contractor effort conducted over more than two years.

A. T. Kearney, Inc. (Management Consultants) was the prime contractor to the Institute for Water Resources of the U.S. Army Corps of Engineers for the National Waterways Study. Kearney was supported by two subcontractors: Data Resources, Inc. (economics and forecasting) and Louis Berger & Associates (waterway and environmental engineering).

The purpose of the contractor effort has been to develop and analyze alternative strategies for the management of the nation's waterways through the year 2000. This report presents the major findings of the study's technical research, summarizes conclusions drawn from that research, and presents evaluations of four alternative strategies for future management of the waterways. Under the terms of the contract, this document contains no recommendations. Its purpose is to provide the analytical basis for policy recommendations by the Secretary of the Army and to support the formulation of national waterways policy by Congress. No discussion contained in this report should be construed as a recommendation for, or against, any specific project or navigation investment.

This report is supported by ten separate research reports totaling more than 5000 pages in length, as shown on the inside front cover of this document. This research, in turn, was based on review of published reports and studies, original research, interviews, and analysis of an extensive array of data assembled and accessed during this study. The results of the analysis were reviewed at five sets of public meetings held throughout the country at key study milestones. Comments and suggestions from the public were evaluated and incorporated.

Therefore, the purpose of this document is not to repeat the technical discussion of the supporting documents. It is intended to present the major findings and conclusions of the overall effort for managers, legislators, and the general public. Those interested in more detail should refer to the supporting reports.

The remainder of this document is divided into nine parts as follows:

Summary of Key Findings and Conclusions. This section summarizes the major findings and conclusions of the study. These are further explained in the body of the report.

I - Description of the Study. This section reviews the events leading to the study, its objectives and scope.

II - Description of the Present Navigation System. This section describes the present navigation system for shallow draft waterways on the Mississippi River and its tributaries, Gulf and Atlantic Intracoastal waterways, and rivers feeding the Atlantic and Pacific Oceans; the Great Lakes and St. Lawrence Seaway; and the ports and channels which form the ocean navigation system.

III - Description of Navigation System Users. This section discusses the decisionmaking process that drives the logistics of the major industries which use water transportation: agriculture, petroleum, coal, metals, chemicals/fertilizer, and forest products. Particular focus is placed on the role of water transportation in the total logistics system for these industries.

IV - Conclusions from Technical Research. This section presents important conclusions from the extensive technical research conducted during this study. These include conclusions about:

- Available data bases.
- The transportation industry.
- National defense and emergency issues.
- Relationships of navigation to other water uses.
- Future waterways science and technology.
- Environmental issues in navigation.

V - Forecast of Potential Water Transportation Use. All analyses about the future were prepared under six alternative sets of assumptions called NWS scenarios. This section presents the assumptions, forecasting methodology, and six sets of commodity flow projections for waterborne commerce. These are presented as national totals and for each of the industries discussed in Section III.

VI - Factors Affecting Waterway Transportation Capability. This section discusses the engineering, operational, and economic factors which affect the ability of the navigation system to accommodate the projected waterborne tonnages presented in the prior section. The focus is on lock capacity, safety, modal competitiveness, and maintaining adequate navigation capability.

VII - Evaluation of the Present Navigation System. This section presents the results of an analysis of the ability of the present navigation system to accommodate the forecasted commodity flows (under six scenarios). This analysis results in a list of navigation system needs to accommodate projected tonnage.

VIII - Evaluation of Alternative Strategies. This section presents the results of the analysis of four alternative strategies for management of the navigation system over the next 25 years under alternative scenarios of the future. The ability of each strategy to meet the system needs shown in Section VII are evaluated along with the cost of implementing the strategy and a discussion of potential side effects.

To facilitate the review of this document, key conclusions are highlighted wherever they occur in the text.

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SUMMARY OF KEY FINDINGS AND CONCLUSIONS

Conclusions presented throughout this report are summarized below. They are divided into six groups as follows:

- National Interest in Navigation.
- Federal Management of the Navigation System.
- Issues Affecting Navigation.
- Needs of the Navigation System.
- Strategies for Action.
- Implementation.

NATIONAL INTEREST IN NAVIGATION

The nation's navigation system, made up of shallow draft inland waterways, Great Lakes/St. Lawrence Seaway, and coastal ports and channels, does not simply serve the adjacent communities. Instead, the navigation system forms a set of internal transportation arteries and linkages at ports that are critical to the health and competitiveness of several key national industries.

Agriculture depends on the waterway system and coastal and lake ports to move the nation's abundance to world markets, contributing $24 billion to the nation's balance of payments in 1980.

American coal is a critical link in our quest for energy independence and will become an increasingly important asset to support our free world allies. Transportation of coal to domestic power generating plants and to coastal ports for export will be the most rapidly growing use of the navigation system through the remainder of this century.

Finally, efficient transportation of iron ore, coal, and limestone via the Great Lakes to support our domestic steel industry is critical to the nation's defense in the event of a national emergency.

Thus, the navigation system is vital to the economic health and defense of the nation as a whole. As a result, there is a clear national interest in effective water transportation that supersedes the parochial interests of individual communities or regions of the country.

FEDERAL MANAGEMENT OF THE NAVIGATION SYSTEM

The federal government recognized the importance of the navigation system to the nation as a whole as early as 1789 with the passage of the Northwest Ordinance which imposed federal control over the navigation system, superseding the rights of individual states and communities. This federal role has attempted to promote efficient use of the navigation system, smooth the flow of interstate and foreign commerce, safe operation, and promotion of the national defense and has contributed substantially to the development of America.

Since 1824, the Corps of Engineers has been responsible for managing the nation's navigation system, reporting directly to the Congress. The basic process by which decisions are made by the Congress on the allocation of investments in the navigation system and the levels of funding for ongoing operations was established in 1899, with only minor subsequent modification. Although this process has worked reasonably well in a period of increasing budgets (in real terms), analysis during this study suggests that continuation of the present process, with more restricted funding, will result in major navigation system deterioration after the turn of the century.

Traditionally, individual navigation system projects are conceived by local interests and initiated by one of the 36 Corps of Engineers District Offices. The authorization even (to study a potential project) requires specific action and funding by the Congress. The process, from concept to completion, regularly requires 20 years or more, and may require a dozen or more specific Congressional actions. Thus, the progress of an individual navigation project through the process is heavily influenced by the many conflicting priorities of the Congress as well as the nation's interest in the navigation system. As a result, the navigation system has not been developed as a part of a national transportation system, but as a series of individual projects and subsystems.

Once navigation projects have been completed, responsibility for their ongoing operation and maintenance falls to the District Offices of the Corps of Engineers. By and large, this responsibility has been exercised well, as evidenced by a systemwide reliability of more than 99%. Further, the Corps has generally identified the potential bottlenecks and other needs well in advance of their becoming critical. **However, progress to take action on these needs has often bogged down in the approval process.**

In the future, approval is going to become more difficult as the emphasis shifts away from (the relatively glamorous) construction of new waterways and structures to mundane operating and maintenance activities, such as dredging. Further complication of the process stems from legislation and judicial proceedings in the last several years which have created conflicting national goals, particularly in the areas of environmental protection and the rights of states to impose local priorities on the national waterways system. Thus, Congress will have increasing difficulty sorting out priorities and taking timely action on critical navigation system needs.

There is a clear need to establish a streamlined process to ensure the efficient ongoing management of the navigation system as an important national transportation resource.

ISSUES AFFECTING NAVIGATION

To put the management of the nation's navigation system in perspective, it is useful to understand several key issues that set the environment in which the navigation system is operated.

Each mode of transportation (water, rail, pipeline, truck, and air) has an inherent role to play in the nation's transportation system based on its underlying modal characteristics and cost structure. Since most transportation decisions relating to commodities which could potentially be shipped by waterway are, in fact, a part of a far larger logistics decisionmaking process, the transportation modal choice decisions tend to be a stable part of long-term investment strategy decisions. **Thus, reliability of navigation and predictability of cost levels are vital to long-range business planning.**

The major modal competition for domestic waterways transportation are pipelines and railroads. Pipelines carry high-volume

fluid commodities and tend to dominate the transportation of petroleum and petroleum products, leaving only residual movements for domestic marine transportation. Railroads tend to be the alternative mode for most other waterborne movements. In the past, there has been bitter competition between the rail industry and the water carriers to maximize tonnage handled. In the future, a deregulated railroad industry will tend to be a more profit-conscious competitor. **Large shippers will be the driving force to design the lowest cost total logistics process drawing on each mode of transportation for the roles that each can play best.**

The results of the analysis from this study have shown that there is very little interaction between the use of water for navigation and the use of water for other purposes, such as irrigation, hydropower generation, and recreation. The conflicts between navigation and other users do not appear to be major national-level constraints to navigation use and development, except perhaps on the Missouri River where future irrigation development could considerably reduce navigation flows and in the Mississippi River immediately below the Missouri River.

An exhaustive review of the future trends in the design and operation of waterways structures anticipates no significant change in the basic navigation technology in the foreseeable future. However, better management of the existing technology can yield significant productivity gains in the operation of the navigation system.

Significant environmental consequences of navigation are important considerations in the construction of new waterways systems and deepening of ports. Since no extension of the inland navigation system, beyond completion of the present system, is included in the scope of this analysis, environmental consequences of the inland actions suggested in the study are small. More serious environmental consequences could result from actions to deepen coastal ports. However, no general conclusion can be drawn. Each must be considered on a case-by-case basis. The other environmental issue of significance is dredged material disposal. Prescribed disposal techniques may increase the cost of dredging. **Throughout the analysis of this study, provision has been made to incorporate the properly prescribed material disposal which minimizes adverse environmental impact.**

NEEDS OF THE NAVIGATION SYSTEM

A major focus of this study has been to identify the needs for the effective management of the navigation system through the turn of the century. The key needs are:

- **Timely expansion of capacity at constraining locks on major waterways systems.** These include:

  - Lock and Dam 26 on the Mississippi River at Alton, Illinois.
  - Five Canadian locks on the Welland Canal between Lake Erie and Lake Ontario.
  - Gallipolis Lock near Huntington, West Virginia on the Ohio River.
  - Demopolis Lock on the Tombigbee River in Alabama.
  - La Grange Lock on the Illinois Waterway.
  - Peoria Lock on the Illinois Waterway.
  - Marseilles Lock on the Illinois Waterway.
  - Lock and Dam 22 on the Upper Mississippi River.
  - Oliver Lock on the Warrior River near Tuscaloosa.
  - Uniontown Lock on the Ohio River near Evansville.
  - Warrior Lock on the Warrior River in Alabama.
  - Holt Lock on the Warrior River near Tuscaloosa.

- **Minor structural improvements and management actions at all congested locks in the navigation system, where appropriate, to improve utilization of the existing lock chamber capacity.**

- **Inexpensive structural and nonstructural actions to reduce the hazard to navigation at approximately 200 high-risk sites in the navigation system.**

- **Adequate funding of ongoing operation, maintenance, and rehabilitation of the navigation system.**

In addition, to prepare for an extremely sharp increase in coal exports, additional needs would require expansion of the capacity of the following locks:

- Newburgh Lock on the Ohio River near Evansville.
- McAlpine Lock on the Ohio River near Louisville.
- Coffeeville Lock on the Tombigbee Waterway in Alabama.
- Bankhead Lock on the Warrior River near Birmingham.

A prolonged national defense conflict would require expansion of the Sault St. Marie Locks on the St. Mary's River between Lake Superior and Lake Huron.

Finally, it is possible that additional capacity will be needed at the Inner Harbor Lock near New Orleans, at Bonneville Lock on the Columbia, and at the Montgomery Lock on the Ohio River. The national level methodology used during this study was not designed to deal with specific local circumstances. Therefore, it did not confirm these potential needs; however, other Corps of Engineers studies have supported the need for expansion at these three additional locations.

STRATEGIES FOR ACTION

Four possible strategies for the future management of the nation's navigation system were hypothesized and applied to the present system. The conclusions were:

1. Strategy I - Continuation of Present Policies. This strategy continues present management practices under a real budget limited to the present level of funding. **This strategy fails to meet the minimum needs summarized above and leaves the navigation system on the threshold of disaster after the turn of the century.**

2. Strategy II - Reprioritization of a Fixed Budget. This strategy assumes the same fixed budget available under Strategy I but refocuses expenditures to meet the needs of the main line shallow draft inland waterways, Great Lakes, and major coastal ports. **This strategy meets the minimum needs for these systems at the expense of lesser, high-cost waterways and approximately 200 smaller ports.**

3. Strategy III - Full Funding of Minimum System Needs. This strategy meets all the minimum requirements identified above for all present waterways and ports at an additional cost of from $1.1 to $2.1 billion (depending on scenario) more than Strategy II over the next quarter century.

4. Strategy IV - Enhanced Navigation System Capability. This strategy improves the navigation system by deepening and widening channels, deepening ports and taking other actions to enhance the reliability of the system. It costs from $4.1 to $8.3 billion more than Strategy III over 25 years but reduces the logistics cost for domestic commerce by $437 million per year over Strategy III and enhances the competitiveness of American exports in world markets by deepening ports.

These strategies were analyzed for comparison of posssible policy courses only. They should not be construed as recommendations of any specific action.

IMPLEMENTATION

Implementation of an improved management process for the nation's navigation system requires that:

- The navigation system be managed as a national transportation system, responsive to national priorities.

- The navigation system management process be streamlined to provide timely and adequate funding of all necessary actions for smooth and efficient operation.

- Attention be applied to improved operating and cost information systems to provide data bases for better management of the navigation system.

It was not the purpose of this study to evaluate the desirability nor level of potential cost recovery programs for navigation. However, it is clear that the nation's interest would be served, should cost recovery be instituted, by users of the navigation system having a strong voice in the setting of priorities for navigation system expenditures.

Implementation of improved navigation system management along the lines suggested in this report should result in a healthy and viable navigation system that will meet the needs of the nation through the end of this century and beyond.

I - DESCRIPTION OF THE STUDY

This section will trace the events leading to the study, its legislative authorization, and the working objectives and scope.

EVENTS LEADING TO THE STUDY

The National Waterways Study (NWS) was directed by Congress in 1976 in Section 158 of the Water Resources Development Act (Public Law 94-587). The study was the result of a growing concern on the part of Congress, shippers, water carriers, the Corps of Engineers, and others that no comprehensive national framework existed for water transportation policy decisionmaking. Instead, each individual water resource project -- whether for flood control, hydropower, domestic water supply, irrigation, or navigation -- was viewed as a separate undertaking. Thus, each of hundreds of potential water resource projects had been conceived, planned, justified, designed, authorized by the Congress, and constructed, based solely on its own merits, independent of its effect on the rest of the navigation system. These merits may have included the support of national or regional economic development, social benefits, environmental enhancement, or support of national defense.

This piecemeal approach by which Congress controlled the funding of individual projects has resulted in the allocation of funds based more on the level of local support for a project than on its role in an overall national program. To improve the process, the Corps of Engineers requested, and the Congress authorized this National Waterways Study to improve the understanding of the national navigation system and its needs.

LEGISLATIVE AUTHORIZATION

The formal authorization for this study is contained in Section 158 of the Water Resources Development Act of 1976:

> The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to make a comprehensive study and report on the system of waterway improvements under his jurisdiction. The study shall include a review of

> the existing system and its capability for meeting the national needs including emergency and defense requirements and an appraisal of additional improvements necessary to optimize the system and its intermodal characteristics. The Secretary of the Army, acting through the Chief of Engineers, shall submit a report to Congress on this study, within three years after funds are first appropriated and made available for the study, together with his recommendations.

STUDY OBJECTIVES

The working objective of the National Waterways Study has been to:

> IDENTIFY AND ANALYZE ALTERNATIVE STRATEGIES FOR PROVIDING A NAVIGATION SYSTEM TO SERVE THE NATION'S CURRENT AND PROJECTED WATER TRANSPORTATION NEEDS.

The study's focus has been on national strategies -- not on individual projects. Its scope has been limited to the navigation system upon which commercial traffic is carried. Its charter has been to deal with water transportation needs -- and other water uses only to the extent of significant interaction with navigation use.

To meet this objective, the study has:

- Projected the nation's potential requirements for water transportation, considering both complementary and competing modes.

- Assessed the capability of the existing waterways system to meet both current and projected national water transportation needs.

- Examined the relationship between the use of waterways for transportation and for other purposes.

- Developed and evaluated alternative strategies to meet the projected national water transportation needs. These strategies include operational, structural, managerial, and budget allocation policies.

STUDY SCOPE

The nation's waterways for this study have been defined to include the navigation system in use as of December 1978 plus commercial navigation projects which were funded by Congress for construction as of that date. These additions include the Tennessee-Tombigbee Waterway; Red River to Shreveport, Louisiana; a new dam and a single 1,200-foot by 110-foot lock chamber to replace Locks and Dam 26 at Alton, Illinois; replacement of the Vermilion Lock on the Gulf Intracoastal Waterway in Louisiana; two replacement locks on the Ouachita River in Louisiana; an extra chamber at the Pickwick Lock on the Tennessee River; and completion of a 12-foot deep navigation channel for the Mississippi River from Baton Rouge to Cairo, Illinois.

For analytical purposes, the nation's river, lake, and ocean waterways (including ports) were grouped into 61 segments. These are defined and described in Exhibit I, appearing near the end of this report. For reporting purposes, results have been grouped into 22 geographic areas as described in Exhibit I and shown in Figure A on the following page.

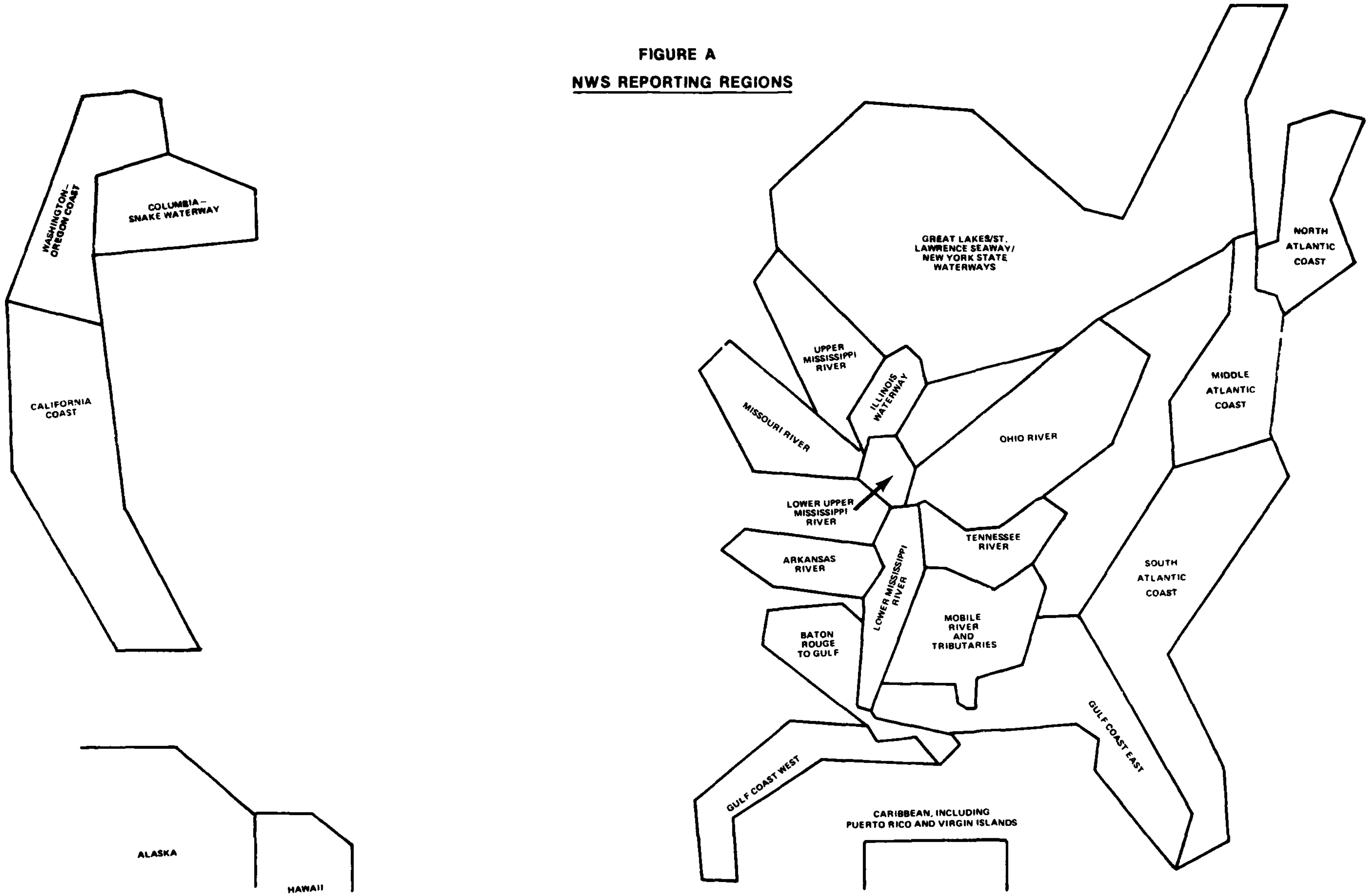
Traffic projections have been prepared for 48 commodity groups and projected from 1977 through 2003 in five-year increments. Description of these commodity groups is shown in Exhibit II at the end of this report. For reporting ease, commodities have been further grouped into 14 categories for presentation.

This study has included the impact of existing user charge legislation (Public Law 95-502) on water carrier cost structures. However, the study did not analyze potential traffic diversions, regional impacts, industry impacts, or alternative user charge schemes. These subjects are topics of a parallel study being conducted jointly by the U.S. Department of Transportation and U.S. Department of Commerce under the provisions of Section 205 of Public Law 95-502.

Throughout the study every attempt has been made to cite data for 1977 (the study base year) wherever possible. Unfortunately, some data are simply not available for 1977 and the closest year was chosen and noted. All cost data are cited in 1977 dollars. Forecasts are projected for 1980, 1985, 1990, 1995, 2000, and 2003 even though only selected years are shown in this document.

FIGURE A

NWS REPORTING REGIONS



II - DESCRIPTION OF THE PRESENT NAVIGATION SYSTEM

This section will describe the composition of the present navigation system: the shallow draft inland waterways (drafts of 14 feet or less), Great Lakes and St. Lawrence Seaway, and ocean ports and channels. Included is a brief discussion of relevant events in the history of the navigation system including key cargo trends and navigation technology.

NATIONAL NAVIGATION SYSTEM

Figure B shows the location of major waterways and ports.

The major shallow draft waterway is the greater Mississippi River system and its tributaries which serve the industrial and agricultural heartland of America from Minneapolis, Chicago, and Pittsburgh to New Orleans. Along the coast of the Gulf of Mexico is a shallow-draft, man-made waterway, the Gulf Intracoastal Waterway, with a number of connecting rivers. The Atlantic Intracoastal Waterway extends from Key West to Norfolk. The Hudson River connects with the New York State Barge Canal to form a shallow draft link from New York to the Great Lakes. On the West Coast, the Columbia-Snake River system serves as a shallow draft artery from Western Idaho to Portland, Oregon.

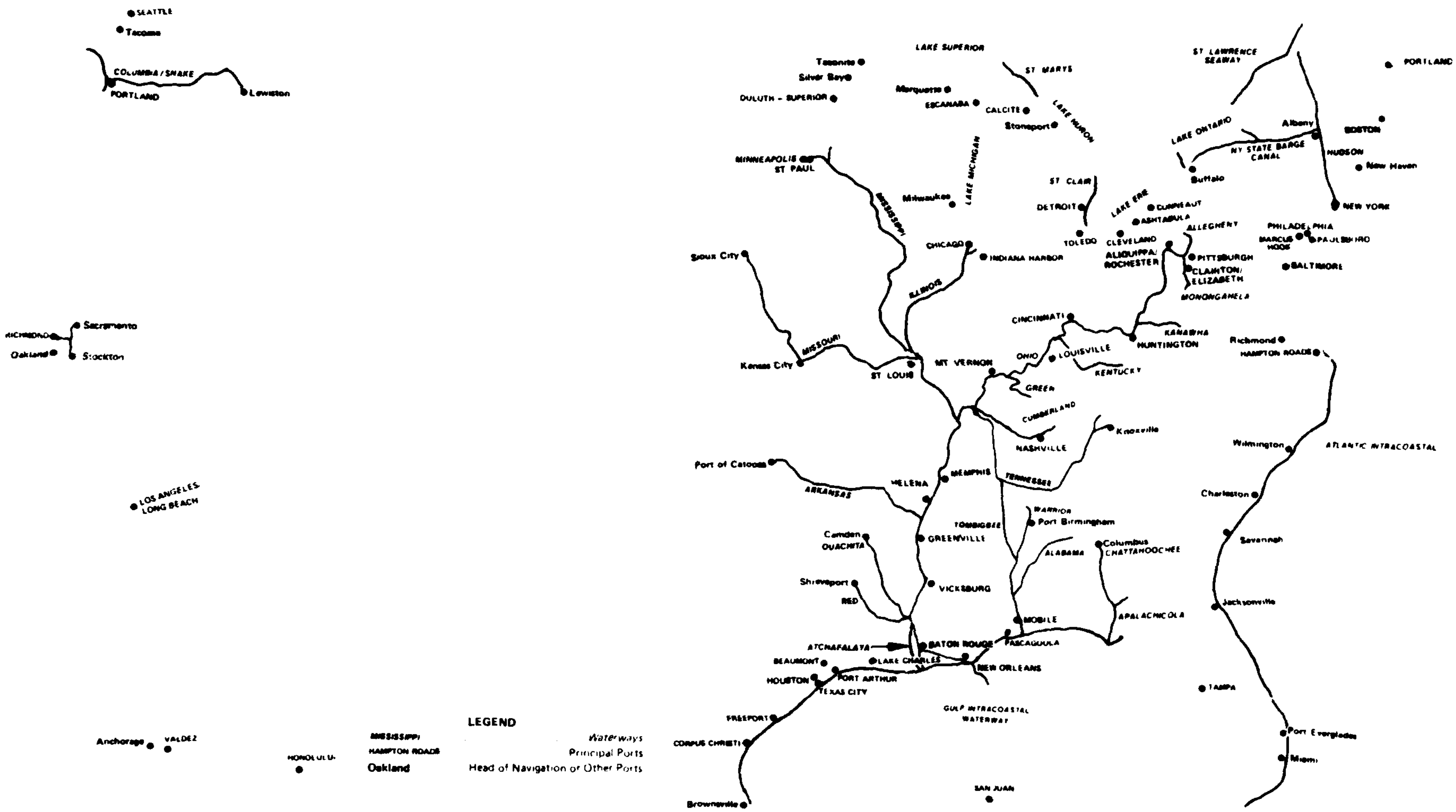
The Great Lakes-St. Lawrence Seaway navigation system serves as a moderately deep draft channel (able to accommodate small oceangoing vessels) from Duluth, Minnesota and Chicago to Detroit, Cleveland, and the Atlantic Ocean via the St. Lawrence River.

Major ocean ports are sited at various locations along the Atlantic, Gulf, and Pacific Coasts as well as in Puerto Rico, Hawaii, and Alaska. Major ports are shown in Figure B.

The existence of this national water transportation system is largely a result of various federal initiatives and activities in response to specific national needs over more than two centuries.

FIGURE B

NATIONAL WATERWAYS



In 1775, the Corps of Engineers was formed to provide for engineering in support of the national defense. As a part of that program, West Point was established as the major source of civil engineering education in the nation. In 1789, the Northwest Ordinance was passed, establishing national oversight and control of the navigation system in order to promote interstate trade, settlement, and economic development. In 1790, the U.S. Coast Guard was formed as the federal maritime police agency.

Much of the early federal interest in the navigation system was related to safety. In 1791, the first federal investment in navigation structures was made in a lighthouse on the Atlantic Coast at Cape Henry, Virginia. In 1802, the Corps of Engineers constructed piers in the Delaware River to support foreign and domestic trade. In 1824, a harbor was constructed by the Corps of Engineers on Lake Erie and the Corps began snagging operations on the Ohio River to remove hazards to navigation.

In 1884, the Corps was given authority by Congress to reconstruct existing navigation structures whenever, in its engineering judgment, such replacement was necessary for safe and effective operation. This authority was amended by Section 6 of the River and Harbor Act of 1909 and restricted by judicial interpretation in 1974. For new water projects (which continued to require Congressional authorization), a formal procedure was first established in 1899, and continues in much the same form today. At the same time, the Corps was given authority to control the placement of potential obstructions to navigation through a permitting process. **Thus, the Corps of Engineers, with the concurrent authorization of Congress as appropriate, has been largely responsible for the development of the national navigation system as we know it today.**

SHALLOW DRAFT WATERWAYS

The following subjects will be addressed for the shallow draft, commercially navigable waterways of the United States as a group: history, physical structures and channel dimensions, federal costs, operating characteristics, and ports.

(a) History of the Shallow Draft Waterways

Shallow draft waterways have been constructed by one of three methods:

- Training the river's natural current (via shoreside structures such as dikes and revetments) to maintain a channel of sufficient width and depth to accommodate commercial navigation. These are called open rivers.

- Constructing a series of shore-to-shore dams across rivers to provide pools of water of sufficient depth for commercial navigation with passage through the dams via navigation locks. These are called canalized rivers.

- Digging or otherwise constructing man-made canals into which water is allowed to flow for navigation.

The first shallow draft waterways were canals constructed in New England in the late 1700s. The Erie Canal, the most famous of these, opened in 1825 between Albany and Buffalo, connecting the Hudson River and the Atlantic with the Great Lakes for the first time. At least 36 other major canals were constructed prior to 1851.

The first commercial navigation on the rivers was by canoe, flat boat, and keel boat. This allowed primarily downstream transportation of agricultural and trade goods (such as furs). In 1807, the first steamboat operation appeared on the Hudson River in New York and its development eventually allowed upstream as well as downstream navigation using paddlewheel technology. Steamboats extended to all of the other major navigable rivers as regional areas of the country became populated. For example, the first steamboat is recorded on the Columbia River in 1850. Steamboats carried passengers, mail, general cargo, and bulk goods (primarily in bags, barrels, and bales) and were the major source of domestic freight transportation. Coal was carried as a bulk commodity in open-topped barges downriver, either floating free or towed by a steamboat. In the 1850s, towboats were specifically designed to push loaded barges lashed together as a single unit. This was a major technological innovation and an advance in the large scale handling of bulk cargoes.

One of the major problems with these wooden hulled steamboats was "snagging" on stumps and logs in the river. Thus, the Corps' initial charter in 1824 was to remove snags from the navigable rivers to improve safety. In 1825, the Corps introduced dredging to remove sand bars and keep channels clear.

By the time of the Civil War, railroads had emerged as the dominant mode of transportation for passengers and general cargo. They were generally considered safer and faster than steamboats and could, of course, travel inland from navigable waterways. The resulting decline of the steamboat for general transportation left the waterways primarily carrying bulk grain from St. Louis to New Orleans (for shipment to the East Coast and Europe) and coal for domestic heating, industrial factory power, and as a boiler fuel for transportation.

In 1879, the Mississippi River Commission was formed to oversee flood control and navigation improvements on the Mississippi River. The Commission's responsibilities included planning and prioritizing projects and obtaining political support for authorization. The Corps of Engineers designed and constructed the navigation improvements.

In 1879, the first dam was constructed from shore-to-shore across the Ohio River. Aids to navigation such as channel markings and lights were established to improve safety. In 1891, the first steel hull was installed on a barge to protect it from snagging and other hazards. In the 1890s, the first internal combustion engine was used on a riverboat to improve safety and efficiency. In 1903, propellers were used for the first time in the river and, in 1906, steel hulls were introduced for powered vessels. After World War I, both diesel engines and tunneled hulls (that allow greater horsepower to be transmitted to the propeller in a restricted shallow channel) were in use. **Thus, all of the major components of today's barge and towing technology were in place by the end of World War I.**

During this war, the sinking of Allied shipping off the Atlantic and Gulf Coasts by U-boats resulted in increased attention to the construction of the Atlantic and Gulf Intracoastal waterways to provide a protected route for the movement of coastal commerce (mostly petroleum). World War I also found the railroad industry deficient in its ability to handle wartime material to and from ports for overseas deployment. As a result, the Secretary of War was authorized in 1920 to promote water transportation to compete with rail and formed a new barge carrier, the Inland

Waterways Corporation, which later became Federal Barge Lines when it was sold to private interests in 1953.

By the beginning of World War II, nine-foot navigation channels had been completed on the Ohio, Upper Mississippi, and Illinois waterways (as well as the Lower Mississippi from St. Louis to New Orleans). The nine-foot project on the Tennessee River became fully operational in 1944.

Since World War II, Congress has authorized and the Corps has constructed or is completing various extensions to the navigation system. These include a nine-foot channel in the Missouri River to Sioux City, the Arkansas waterway system nearly to Tulsa, the Columbia-Snake system, various rivers feeding the Gulf of Mexico, and (most recently) the Tennessee-Tombigbee waterway to link the Tennessee River with the Gulf of Mexico at Mobile.

The nation's shallow draft waterways are shown in Figures C and D on the following pages. Figure C shows the greater Mississippi River system and Gulf. Figure D shows the East Coast and West Coast shallow draft waterways. Major inland ports (based on tonnage) are shown. Smaller rivers and side channels are not shown but are included in subsequent analysis along with their connecting main channels.

FIGURE C

GREATER MISSISSIPPI SYSTEM AND GULF COAST WATERWAYS: STRUCTURES AND PRINCIPAL PORTS

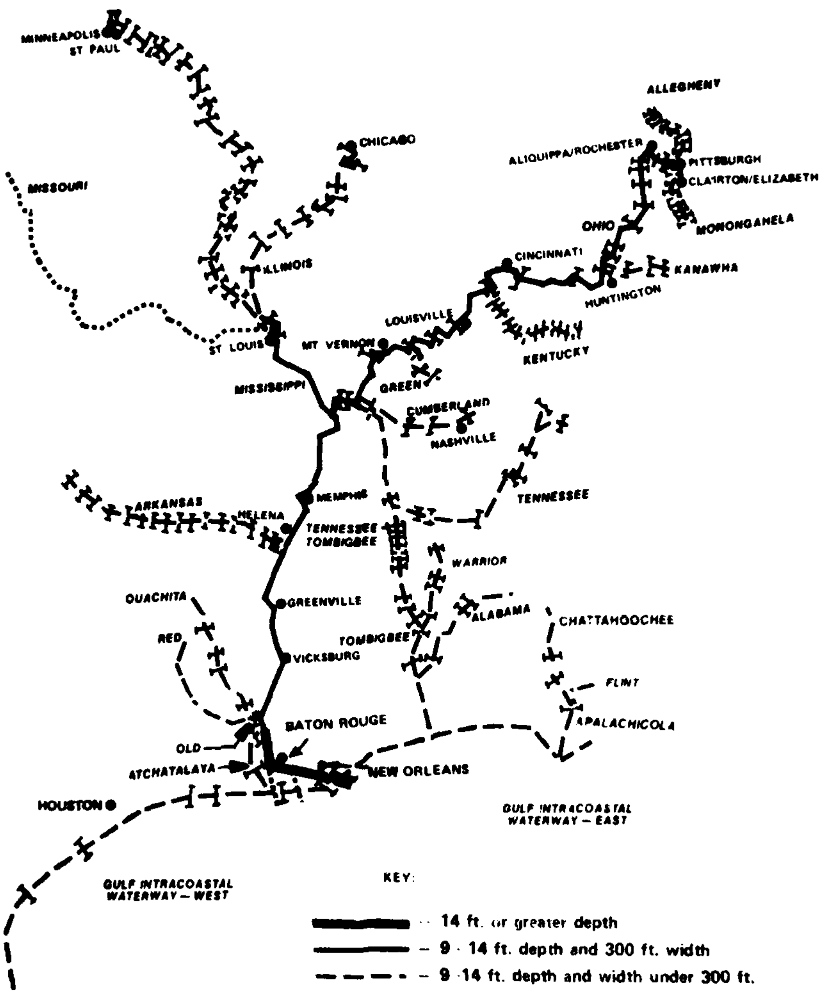
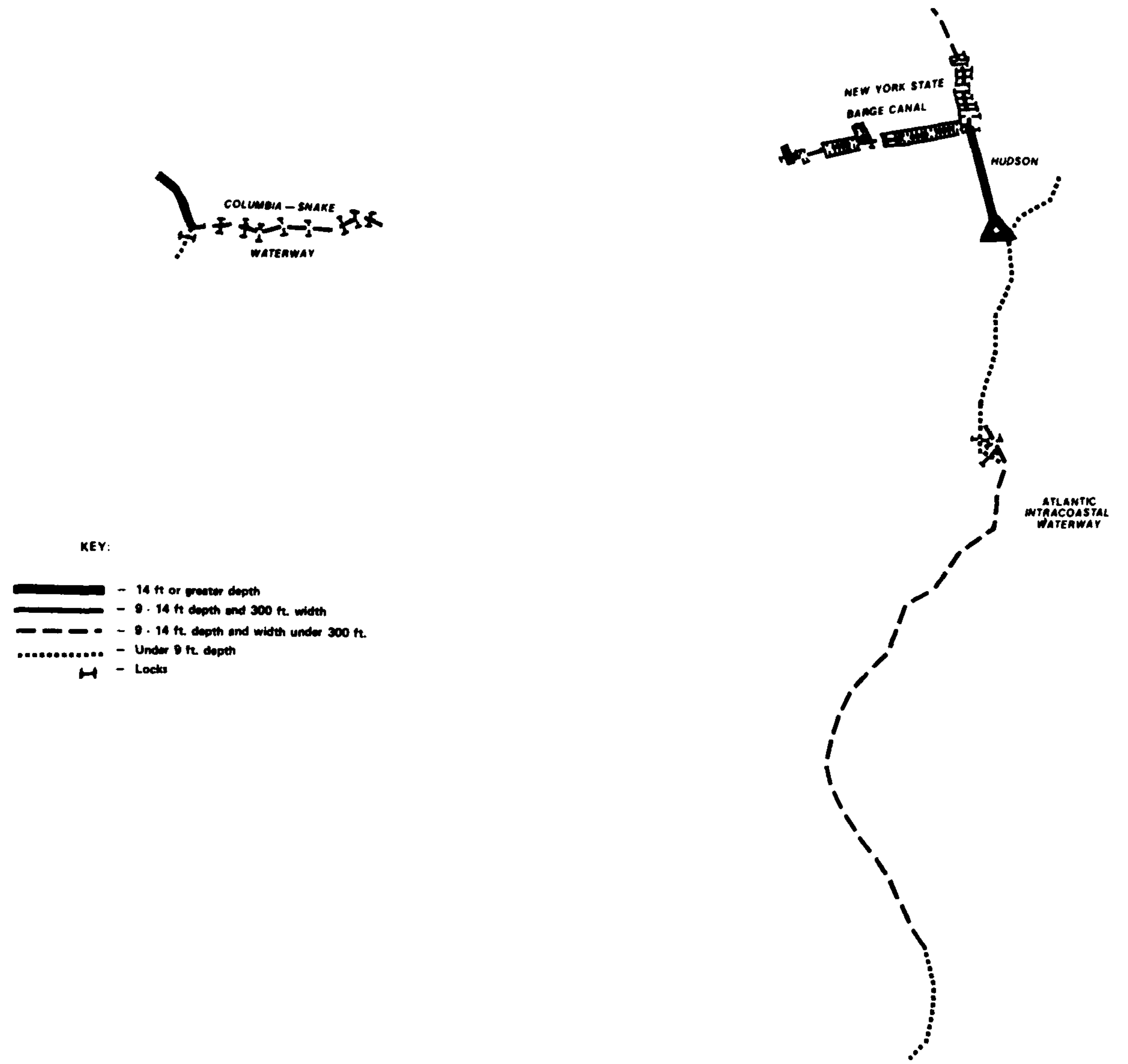


FIGURE D

EAST AND WEST COAST WATERWAYS: STRUCTURES



(b) Physical Structures and Channel Dimensions

Table 1, shows the physical characteristics of commercially important shallow draft waterways. Each shallow draft NWS region (as defined in Exhibit I) is shown. In some cases, subregions are shown to provide clarification.

In total, 189 navigation locks are shown with a median age of approximately 40 years. This ranges from a low of just 7 years on the relatively new Arkansas waterway to 79 years on the Kentucky River. Channel widths range from a low of just 75 feet on the Kentucky River (allowing tows of only one barge in width for two-way navigation) to 300 feet or more on some portions of the lower Mississippi and Ohio Rivers (allowing tows of up to five barges wide). Depths range from as shallow as 6 feet on some smaller rivers such as the Kentucky and Ouachita to as deep as 12 feet on a reliable basis on the Lower Mississippi River and on the Gulf Intracoastal Waterway.

Most rivers are open 12 months of the year for navigation. However, the Upper Mississippi River (above Winfield, Missouri) is closed for approximately three months each year due to icing. The Missouri is closed for four months due to the low seasonal release of water from the upstream reservoirs.

These characteristics affect the operation of commercial navigation on the waterway. It takes time to pass through each lock (30 to 90 minutes if there is no congestion). Wider and deeper channels allow the use of larger tows carrying more cargo on each trip. The length of the season affects the utilization of fixed assets devoted to serving that river segment.

(c) Federal Costs of Shallow Draft Waterways

The estimated federal costs for the construction and ongoing operations and maintenance of the nation's shallow draft waterways system are shown in Table 2.

TABLE 1

SHALLOW DRAFT WATERWAYS: PHYSICAL CHARACTERISTICS OF COMMERCIALLY IMPORTANT WATERWAYS

REGION SEGMENT	TYPE OF WATERWAY(1)	LOCKS(2) NUMBER(3)	LOCKS(2) MEDIAN AGE (YEARS)	CONTROLLING CHANNEL DIMENSIONS WIDTH (FEET)	CONTROLLING CHANNEL DIMENSIONS DEPTH (FEET)(4)	SEASON LENGTH (MONTHS)
UPPER MISSISSIPPI	CANALIZED	29	42	200-300	9	9
LOWER UPPER MISSISSIPPI	CANALIZED, OPEN	4	26	200-300	9	12
LOWER MISSISSIPPI	OPEN	0	-	300	9-12	12
BATON ROUGE TO GULF						
MISSISSIPPI FROM BATON ROUGE SOUTH(5)	OPEN	0	-	300-500	40	12
OUACHITA-BLACK AND RED RIVERS	CANALIZED	4	54	100	6-9	12
OLD AND ATCHAFALAYA RIVERS	CANALIZED	2	20	125	12	12
BATON ROUGE - MORGAN CITY BYPASS	CANAL	2	20	125	11	12
ILLINOIS WATERWAY	CANALIZED	8	42	150-300	9	12
MISSOURI RIVER	OPEN	0	-	250	8.5	8
OHIO RIVER						
OHIO RIVER	CANALIZED	39	17	300	9	12
MONONGAHELA	CANALIZED	13	27	250-400	9	12
ALLEGHENY	CANALIZED	8	44	250-350	9	12
KANAWHA	CANALIZED	6	42	400	9	12
KENTUCKY	CANALIZED	14	79	75	6	12
GREEN	CANALIZED	2	22	200	9	12
CUMBERLAND	CANALIZED	4	19	300	9	12
TENNESSEE RIVER	CANALIZED	10	32	250	9	12
ARKANSAS RIVER	CANALIZED	17	7	165-250	9	12
GULF COAST WEST	CANALS, OPEN	5	27	125	9-12	12
GULF COAST EAST	CANALIZED, CANALS, OPEN	5	22	100-150	3-12	12
MOBILE RIVER AND TRIBUTARIES	CANALIZED, OPEN	9	12	150-200	9	12
SOUTH ATLANTIC - MIDDLE ATLANTIC COASTS						
ATLANTIC INTRACOASTAL WATERWAY	CANAL	0	-	85-90	4-12	12
GREAT LAKES/ST. LAWRENCE SEAWAY						
NEW YORK STATE BARGE CANAL	CANAL	0	-	104	14	'2
COLUMBIA-SNAKE	CANALIZED	8	12	250	15	12
TOTAL		189				

Notes: (1) Open rivers are rivers with no locks and dams. Canalized rivers are natural rivers that have been dammed to provide navigation depths and/or storage in reservoirs. Canals are man-made channels, often including locks, constructed for navigation and/or other purposes.
(2) Commercially significant locks only.
(3) Numbers of lock chambers.
(4) Channels are maintained at greater depth (one to three feet) to permit vessels or barges to operate safely at the indicated depths.
(5) Deep draft waterway.

Source: NWS, Engineering Analysis of Waterways System, 1981.

TABLE 2

SHALLOW DRAFT WATERWAYS: FEDERAL COSTS EXPENDED BY CORPS OF ENGINEERS
(ALL COSTS IN MILLIONS OF 1977 DOLLARS)

REGION SEGMENT	ESTIMATED REPLACEMENT COST (1)	ANNUAL DREDGING (2) VOLUME (1000 cu. yd.)	COST	ANNUAL OTHER OPERATIONS AND MAINTENANCE COSTS (2)	TOTAL OPERATIONS AND MAINTENANCE COSTS (2)
UPPER MISSISSIPPI	$ 3,038	2,729	$ 2.7	$ 21.6	$ 24.3
LOWER UPPER MISSISSIPPI	1,734	6,039	3.2	6.9	10.1
LOWER MISSISSIPPI(3)	217	34,402	9.2	7.5	16.7
BATON ROUGE TO GULF(4)					
OUACHITA-BLACK AND RED RIVERS	24	2,450	1.3	1.5	2.8
OLD AND ATCHAFALAYA RIVERS	2	115	0.0	0.5	0.5
BATON ROUGE - MORGAN CITY BYPASS	96	635	0.3	0.3	0.6
ILLINOIS WATERWAY	585	2,512	1.7	3.2	4.9
MISSOURI RIVER	388	4,848	4.0	3.6	7.6
OHIO RIVER					
OHIO RIVER	9,429	2,353	2.8	9.3	12.1
MONONGAHELA	1,202	71	0.2	0.0	0.2
ALLEGHENY	275	40	0.1	0.0	0.1
KANAWHA	230	11	0.1	0.0	0.1
KENTUCKY	113	110	0.1	2.1	2.2
GREEN	54	75	0.1	0.9	1.0
CUMBERLAND	424	89	0.2	3.0	3.2
TENNESSEE RIVER	2,426	30	0.1	3.0	3.1
ARKANSAS RIVER	1,598	3,294	2.4	12.6	15.0
GULF COAST WEST	607	12,329	5.4	2.2	7.6
GULF COAST EAST	829	3,059	2.2	4.4	6.6
MOBILE RIVER AND TRIBUTARIES	622	3,994	1.8	3.0	4.8
SOUTH ATLANTIC - MIDDLE ATLANTIC COASTS	281	8,039	9.4	8.0	17.4
ATLANTIC INTRACOASTAL WATERWAY					
GREAT LAKES/ST. LAWRENCE SEAWAY					
NEW YORK STATE BARGE CANAL	115(5)	-	-	-	-
COLUMBIA-SNAKE	99	6,892	2.6	3.0	5.6
TOTAL	$24,388	94,116	$49.9	$96.6	$146.5

Notes: (1) Based on historical first costs adjusted for inflation to 1977.
(2) Average for 3 to 5 years ending 1977.
(3) These costs do not include the costs of deepening the Lower Mississippi to 12 feet funded under the jurisdiction of the Mississippi River Commission.
(4) Federal costs for the Lower Mississippi from Baton Rouge south are shown in Table 9.
(5) Federal costs for the Troy Lock.

Source: Corps of Engineers, NWS Inventory.

The estimated replacement cost of the nation's shallow draft waterway system in 1977 dollars is approximately $24 billion. Each year, the Corps of Engineers spends approximately $147 million to maintain and operate the system. About $50 million of this goes for dredging to keep channels free of sandbars. Approximately $97 million is consumed for power and labor to operate the 189 locks in the system and for maintenance on the locks and river training structures that make navigation possible. In the latter case, these costs are often an allocation to navigation of a total expenditure to maintain multipurpose structures designed to control floods, provide recreation facilities, and generate hydropower, as well as support navigation.

It is useful to note that the navigation system is very capital intensive. Annual operations and maintenance are well less than 1% of the estimated investment in the system.

(d) Operating Characteristics of Shallow Draft Waterways

Table 3 shows the operating characteristics of shallow draft waterways.

The operating drafts for barge tows are shown in the first column of the table. These parallel the authorized channel depths shown in Table 1. The depth to which a barge can be loaded determines its carrying capacity. A standard 35-foot by 195-foot barge (known as a jumbo) can hold approximately 1,500 tons at a nine-foot draft. At 12 feet, the same barge can hold approximately 2,000 tons.

Wider channels and bend radii allow the assembling of a larger number of barges into a single tow. Tow size ranges from just one on the Kentucky or two on the Ouachita to 15 on the Upper Mississippi and as many as 45 on the Lower Mississippi River. Although the horsepower of the towboat necessary to push the larger tow is greater, overall vessel investment and crew requirements do not increase proportionately.

Wide open rivers without locks and dams generally allow faster travel times (e.g., six miles per hour in the Lower Mississippi versus only three to four miles an hour on most of the other rivers where locks are the principal sources of delay). Faster

TABLE 3

SHALLOW DRAFT WATERWAYS: OPERATING CHARACTERISTICS

REGION SEGMENT	DRAFT (FEET)	COMMON MAXIMUM TOW SIZE(1)	AVERAGE SPEED (MPH)(2)	1977 LINEHAUL COSTS(3) (MILLS/TON-MILE)
UPPER MISSISSIPPI	9	15	4	7.5
LOWER UPPER MISSISSIPPI	9	25	4	8.1
LOWER MISSISSIPPI	9-12	45	6	5.0
BATON ROUGE TO GULF				
MISSISSIPPI FROM BATON ROUGE SOUTH	40	45	6	4.6
OUACHITA-BLACK AND RED RIVERS	6-9	2	4	13.5
OLD AND ATCHAFALAYA RIVERS	12	4	4	15.1
BATON ROUGE - MORGAN CITY BYPASS	11	5	4.5	10.8
ILLINOIS WATERWAY	9	15	4	7.2
MISSOURI RIVER	8.5-9	8	4.4	16.2
OHIO RIVER				
OHIO RIVER	9	15	4.5	7.6
MONONGAHELA	9	4	4	10.3
ALLEGHENY	9	6	4	17.2
KANAWHA	9	9	3	33.4
KENTUCKY	6	1	4	23.6
GREEN	9	4	4	8.4
CUMBERLAND	9	8	4	12.2
TENNESSEE RIVER	9	15	4.3	9.7
ARKANSAS RIVER	9	9	4	14.4
GULF COAST WEST	9-12	5	4.5	11.4
GULF COAST EAST	3-12	5	4	10.8
MOBILE RIVER AND TRIBUTARIES	9	6	4	11.0
SOUTH ATLANTIC - MIDDLE ATLANTIC COASTS				
ATLANTIC INTRACOSTAL WATERWAY	4-12	2	4	(4)
GREAT LAKES/ST. LAWRENCE SEAWAY				
NEW YORK STATE BARGE CANAL	14	1	3	20.5
COLUMBIA-SNAKE	12	5	4	8.0

Notes: (1)Expressed in jumbo (35' x 195') barge equivalents.
(2)After delays are taken into account. Average of up and downstream.
(3)Weighted by the average mix of commodities moving in domestic commerce during 1977. A mill is a tenth of a cent.
(4)Not calculated.

Sources: NWS, <u>Engineering Analysis of Waterways System</u>. <u>Evaluation of the Present Navigation System</u>, 1981.

speeds, of course, generate more ton-miles of transportation per hour than slower speeds.

Combining all of these operating characteristics into an index of the average linehaul cost shows the relative economic efficiency of operations on each waterway. Estimated 1977 linehaul costs range from about five mills (tenths of a cent) per ton-mile on the Lower Mississippi to seven or eight mills per ton-mile on the Illinois, Ohio, and Upper Mississippi Rivers, to over 23 mills per ton-mile on the Kentucky and 33 mills on the Kanawha Rivers, both short spurs off the Ohio.

(e) Shallow Draft Ports

Table 4 lists the principal shallow draft inland ports and shows the major commodities handled by each. Coastal ports, such as New Orleans, and Great Lakes ports, such as Chicago, also handle substantial amounts of shallow draft commerce, but are discussed later in this section under other headings.

TABLE 4

SHALLOW DRAFT WATERWAYS: PRINCIPAL PORTS

REGION PORT NAME	1977 SHALLOW DRAFT COMMERCE IN MILLIONS OF TONS FARM AND FOOD PRODUCTS	PETROLEUM(1)	COAL	METALS(2)	CHEMICALS/ FERTILIZER(3)	OTHER	TOTAL
UPPER MISSISSIPPI							
ST. PAUL, MINNESOTA	1.9	1.6	1.7	0.1	0.2	1.3	6.8
MINNEAPOLIS, MINNESOTA	0.5	0.2	1.1	0.1	0.0	0.6	2.5
LOWER UPPER MISSISSIPPI							
METROPOLITAN ST. LOUIS	4.8	8.1	4.8	0.8	1.4	2.6	22.5
LOWER MISSISSIPPI							
MEMPHIS, TENNESSEE	1.6	6.0	1.7	0.5	0.4	1.7	11.9
HELENA, ARKANSAS	0.7	2.4	0.0	0.0	0.2	0.2	3.5
GREENVILLE, MISSISSIPPI	0.4	2.0	0.0	0.0	0.0	0.6	3.0
VICKSBURG, MISSISSIPPI	0.6	1.8	0.0	0.1	0.0	0.6	3.1
OHIO RIVER							
CLAIRTON/ELIZABETH, PENNSYLVANIA	0.0	0.3	8.7	0.0	0.4	0.2	9.6
PITTSBURGH, PENNSYLVANIA	0.0	1.7	3.0	0.7	0.4	1.7	7.5
ALIQUIPPA/ROCHESTER, PENNSYLVANIA	0.0	0.4	4.2	0.4	0.1	0.2	5.3
HUNTINGTON, WEST VIGINIA	0.0	3.3	13.1	0.0	0.1	0.6	17.1
CINCINNATI, OHIO	1.7	3.5	2.2	0.6	1.3	1.1	10.4
LOUISVILLE, KENTUCKY	0.3	3.4	2.5	0.2	0.3	2.3	9.0
MT. VERNON, INDIANA	0.7	3.0	0.0	0.0	0.0	0.0	3.7
NASHVILLE, TENNESSEE	0.0	1.3	0.0	0.3	0.0	1.7	3.3

Notes: (1)Crude petroleum and petroleum products.
(2)Metallic ores and primary metal products as defined in Exhibit II plus limestone.
(3)Includes sulfur and phosphate rock.

Source: Corps of Engineers, Waterborne Commerce of the United States, 1977.

Note that 7 of the 15 largest inland ports are on the Mississippi River, mostly handling grain shipments, coal receipts (in 1977), and petroleum receipts. Seven more are on the Ohio River, mostly shipping coal and receiving petroleum products.

GREAT LAKES AND ST. LAWRENCE SEAWAY

This section will briefly discuss the history, physical structures and operating characteristics, public costs, and ports of the Great Lakes and St. Lawrence Seaway System.

Figure E shows the Great Lakes and St. Lawrence Seaway and its principal U.S. ports. The five lakes, from west to east, are: Superior, Michigan, Huron, Erie and Ontario. The St. Lawrence River feeds from the eastern end of Lake Ontario to the Atlantic Ocean through Canada.

(a) History of the Great Lakes and St. Lawrence Seaway

The Great Lakes were first mapped in 1618-32 by French explorers. Its first cargoes consisted primarily of furs taken out by canoe for transshipment in Montreal to Europe.

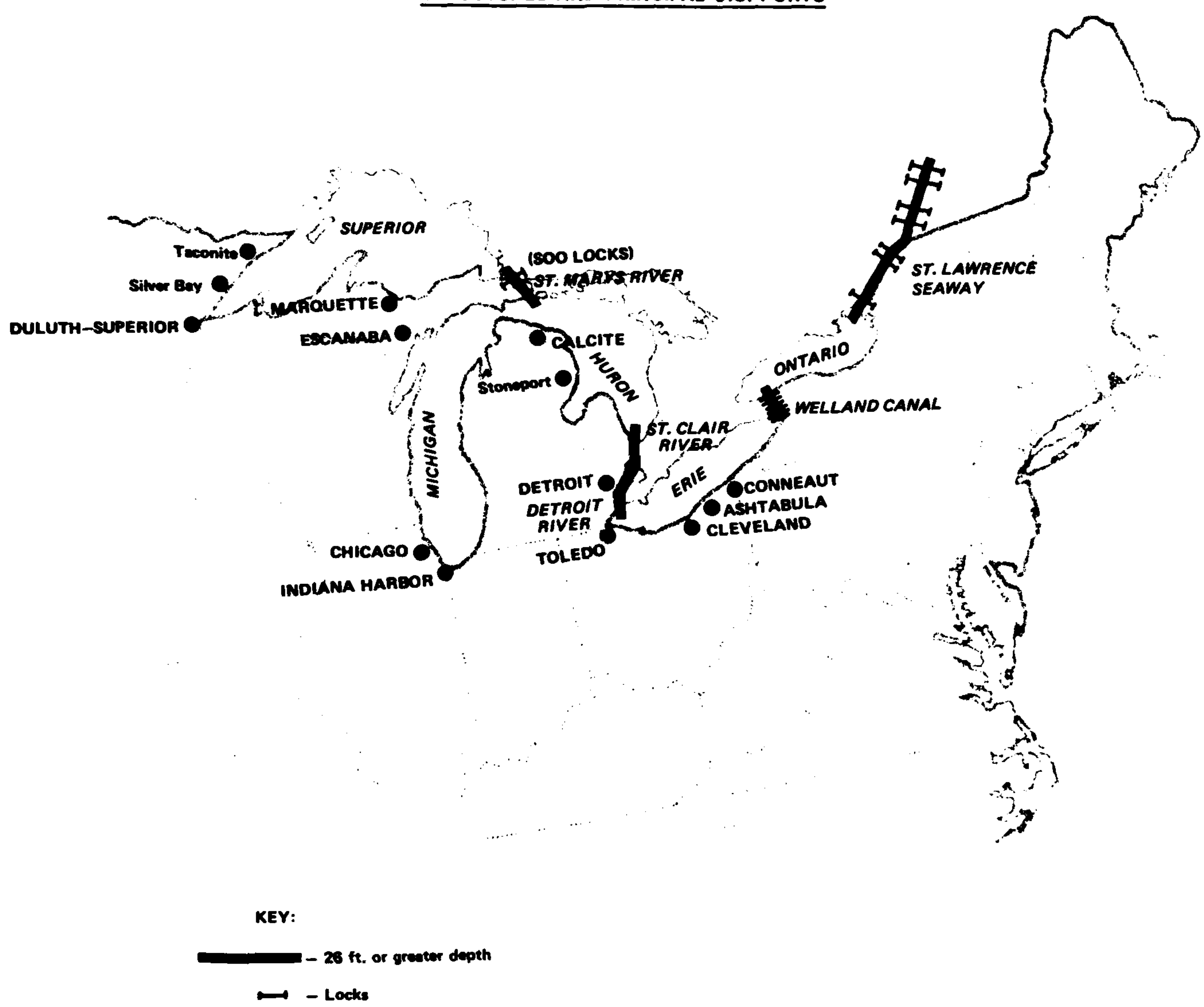
In 1797, the first lock was built on the St. Mary's River between Lakes Superior and Huron. In 1818, the first paddlewheel steamboat plied the lakes. In 1824, the first federal harbor improvements were made on Lake Erie. In 1825, the Erie Canal connected with Lake Erie at Buffalo and opened a much shorter route to the Atlantic via New York. In 1829, the first canal connecting Lake Erie and Lake Ontario was completed (bypassing Niagara Falls), thus the Great Lakes became an integrated transportation system physically connected to the Atlantic Ocean. During this time, the lakes saw rapid growth in passenger traffic and general commerce with the result that water transportation on the lakes played a major role in the settlement of the Midwest.

In the 1830s, copper was discovered on the Upper Peninsula of the State of Michigan and, in 1844, iron ore was discovered in Minnesota, near Lake Superior. In 1855, a new lock and canal was constructed on the St. Marys River to support this trade.

FIGURE E

GREAT LAKES AND SEAWAY:

STRUCTURES AND PRINCIPAL U.S. PORTS



The Civil War helped promote traffic on the Great Lakes in support of the Union war effort with substantial growth in lumber traffic from Wisconsin and Minnesota to the cities bordering the lakes. Around the turn of the century, the major growth of traffic on the lakes was in support of the steel industry which had settled in Chicago, Detroit, Cleveland, and Pittsburgh. Cargoes of iron ore, limestone, and coal were dominant. General cargo, however, declined as the railroads carried the majority of the passenger and general freight cargoes.

From 1914 to 1932, the Welland Canal, between Lake Ontario and Lake Erie, was rebuilt to its present configuration.

During World War II, lake fleets provided crews and masters for mobilization for the ocean trades in support of the war effort. As a result of the crew shortage and the wartime levels of steel production, the operating season of the lakes was extended from its normal eight months to ten months and more.

In 1959, the modern St. Lawrence Seaway was completed as a joint U.S.-Canadian undertaking to accommodate oceangoing vessels of a size common at that time. As a result, foreign trade from the lakes increased somewhat. However, oceangoing general cargo technology was transformed by the advent of containerization, resulting in a new generation of oceangoing container ships, and dramatically changing the economies of general cargo ocean transportation to the detriment of the Seaway. Therefore, virtually all of the trade on the lakes today is made up of bulk cargoes of iron ore, limestone, and coal to feed the steel industry, steel products (both import and export), grain for export, and the distribution of petroleum products. General cargo traffic, while important to Midwest ports, is a very small percentage of total tons handled.

(b) Physical Structures and Channel Dimensions

Table 5 shows the physical characteristics of the constraining channels of the Great Lakes and Seaway navigation system. Open water navigation on the lakes is not a constraint.

TABLE 5

GREAT LAKES AND SEAWAY: PHYSICAL CHARACTERISTICS

SEGMENT	LOCKS NUMBER	LOCKS MAXIMUM CHAMBER SIZE WIDTH	LOCKS MAXIMUM CHAMBER SIZE LENGTH	LOCKS MEDIAN AGE (YEARS)	MAXIMUM DRAFT (FEET)	SEASON LENGTH (MONTHS)
ST. LAWRENCE RIVER	7	80	766	18	26	8.5
WELLAND CANAL	8 (1)	80	766	N/A	27	8
DETROIT RIVER	0	-	-	-	28	12 (2)
ST. CLAIR RIVER	0	-	-	-	27	12 (2)
ST. MARYS RIVER	4 (3)	110	1,200	46	28	8.5
TOTAL	19					

Notes: (1) Does not include dual chambers at three sites.
(2) Year round navigation is not available at all harbors.
(3) U.S. locks only.

N/A = Not available from historical records.

Source: Corps of Engineers, North Central Division.

There are 19 locks in the Great Lakes/Seaway system. In addition, there is a Canadian chamber at the St. Marys River that is rarely used. The Welland Canal locks and five of the St. Lawrence River locks are Canadian owned and controlled. The other two locks on the St. Lawrence River are owned by the St. Lawrence Seaway Development Corporation, a federally chartered corporation under jurisdiction of the U.S. Department of Transportation. Between the lakes and the ocean, the constraining width is 80 feet, length is 766 feet, and maximum draft is 26 feet. The maximum deadweight tonnage which can be accommodated by these locks is approximately 29,000 tons. Between the Lake Superior mineral producing areas and the steel mills, the largest lock chamber is 110 feet by 1,200 feet with a maximum draft of 28 feet. The maximum vessel size is 64,000 deadweight tons. (Note that the fresh water lakes support less tonnage than salt water for an equivalent vessel.)

Season length ranges from eight months on the Welland Canal (restricting year-round access to the Atlantic Ocean) to a full twelve months on some local moves in Lakes Erie, Huron, and Michigan, and connecting channels.

(c) Federal Costs for the Great Lakes and St. Lawrence Seaway

Table 6 presents the estimated U.S. federal costs for replacement, dredging, and other operations and maintenance expenses of the Great Lakes/Seaway.

TABLE 6

GREAT LAKES AND SEAWAY: FEDERAL COSTS(1) EXPENDED BY CORPS
(ALL COSTS IN MILLIONS OF 1977 DOLLARS)

SEGMENT	ESTIMATED REPLACEMENT COST(3)	ANNUAL DREDGING(2) VOLUME (1000 CU. YD.)	ANNUAL DREDGING(2) COST	ANNUAL OTHER OPERATION AND MAINTENANCE COSTS(2)	TOTAL OPERATION AND MAINTENANCE COSTS(2)
LAKE ONTARIO AND ST. LAWRENCE SEAWAY	$ 461	426	$ 0.5	$0.5	$ 1.0
LAKE ERIE	1,676	4,292	5.9	2.8	8.7
LAKE HURON	1,130	716	5.4	4.6	10.0
LAKE MICHIGAN	1,159	1,344	2.8	1.1	3.9
LAKE SUPERIOR	411	231	0.6	0.3	0.9
TOTAL	$4,837	7,009	$15.2	$9.3	$24.5

Notes: (1) Does not include St. Lawrence Seaway and Canadian facilities funded from tolls.
(2) Annual average for 3 to 5 years ending 1977.
(3) Based on historical first costs adjusted for inflation. The estimated replacement costs of the St. Lawrence River and Welland Canal locks average $3.2 billion in 1977 dollars, not included in table totals.

Source: Corps of Engineers, NWS Inventory.

The estimated replacement cost of the Corps facilities on the Great Lakes and St. Lawrence Seaway is slightly less than $5 billion. Annual dredging of about 7 million cubic yards, costing $15 million, is devoted mostly to federally maintained harbors. Other operations and maintenance expenses, including lock operation, is slightly more than $9 million, bringing **total annual costs of Great Lakes and Seaway operation by the Corps of Engineers to $24.5 million for the U.S.**

Note that Canadian operations and maintenance costs are not included in these data nor are the costs of facility operations by the St. Lawrence Seaway Development Corporation. The Canadian government and the St. Lawrence Seaway Development Corporation collect tolls to cover these operating costs. Estimated replacement cost of non-Corps facilities on the Seaway is $3.2 billion in 1977 dollars. No estimate of Canadian operating costs was provided for this study. Seaway Development Corporation costs were $5.2 million in 1977, covered by $8.6 million in revenues.

(d) Great Lakes and St. Lawrence Seaway Ports

Table 7 displays characteristics of the ten largest U.S. ports on the Great Lakes and St. Lawrence Seaway based on annual tonnage handled.

TABLE 7

GREAT LAKES AND SEAWAY: PRINCIPAL U.S. PORTS(1)

WATERWAY PORT NAME	CONTROLLING DRAFT (FEET)	1977 COMMERCE IN MILLIONS OF TONS(2)						
		FARM AND FOOD PRODUCTS	PETROLEUM(3)	COAL	IRON ORE	LIMESTONE	OTHER	TOTAL
LAKE SUPERIOR								
DULUTH-SUPERIOR	27	6.2	0.3	4.4	20.4	0.8	1.3	33.4
LAKE MICHIGAN								
CHICAGO	27	1.6	5.0	3.1	5.6	1.5	0.3	17.1(4)
INDIANA HARBOR	27	0.0	4.7	0.0	7.4	1.9	0.0	14.0
ESCANABA	N/A	0.0	0.2	0.2	9.1	0.0	0.0	9.5
LAKE HURON								
CALCITE	N/A	0.0	0.0	0.0	0.0	12.0	0.0	12.0
DETROIT RIVER								
DETROIT	27	0.1	1.4	6.8	7.8	4.7	3.8	24.6
LAKE ERIE								
ASHTABULA	27	0.0	0.0	5.6	5.4	0.5	0.1	11.6
CLEVELAND	27	0.1	0.5	0.0	10.5	2.3	2.7	16.1
CONNEAUT	27	0.0	0.0	8.0	5.3	1.8	0.0	15.1
TOLEDO	27	4.0	0.7	13.4	3.5	0.1	1.5	23.2

Notes: (1) Does not include the many privately developed and maintained ports for which port data are not published.
(2) Total U.S. domestic lakewise and foreign traffic only.
(3) Crude petroleum and petroleum products.
N/A = Not available from published records.
(4) Deep draft tonnage only.

Source: Corps of Engineers, Waterbone Commerce of United States, 1977.

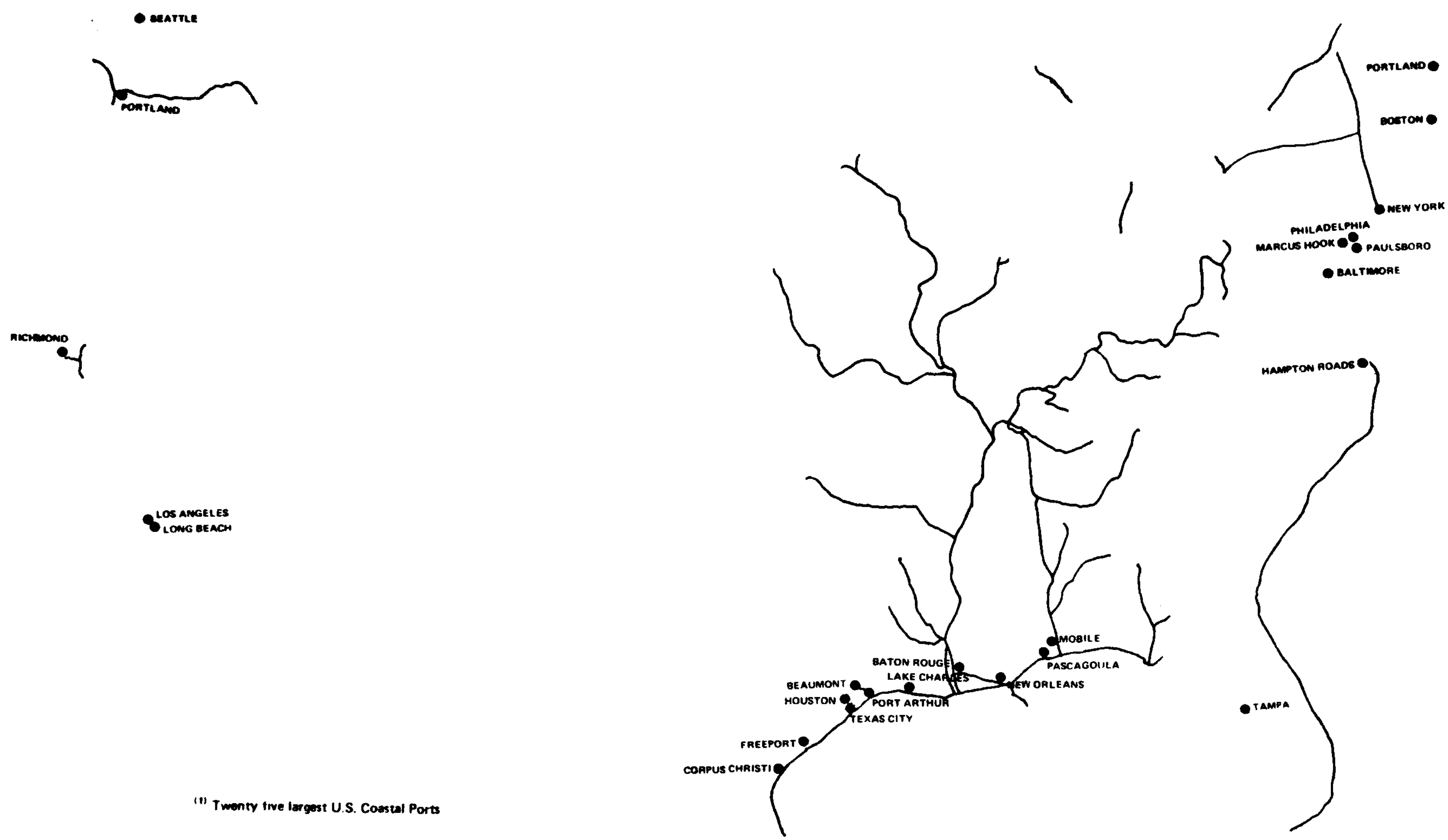
The ten largest ports primarily serve the steel industry for the movement of coal, iron ore, and limestone. Only Duluth, Toledo, and Chicago are significant shippers of grain. Only Chicago, Indiana Harbor and Detroit handle petroleum products in quantity. Steel products and general cargo are both included in the "other" category.

COASTAL PORTS AND CHANNELS

This discussion will focus on the history of ocean transportation serving the United States for both domestic and foreign trade, Federal costs associated with ports and channels, and the physical and operating characteristics of 25 major ocean ports.

Figure F on the next page displays a map of principal U.S. coastal ports.

FIGURE F
COASTAL PORTS (1)



(1) Twenty five largest U.S. Coastal Ports

(a) History of U.S. Ocean Transportation

The oceans were often the most effective means of long distance travel available to colonial seaboard cities. As a result, ocean intercity transportation was the major form of commerce during colonial periods. Thus, the first federal actions taken to improve the navigation system were on the coasts and at coastal ports.

In 1819, the first oceangoing steam vessel was developed and proven technically. However, fear of fire at sea delayed its economic exploitation. In the meantime, large clipper ships were built beginning in 1839 to handle a great deal of foreign ocean trade. The first propeller was developed around 1840 and the first-iron hulled ships equipped with propellers were built in Britain in 1843. Intercoastal trade between the Atlantic and Pacific was given impetus by the California gold rush of 1849 in the absence of a transcontinental land transportation system. The federal government subsidized U.S. steamship trades in the 1840s and 1850s but this was withdrawn just prior to the Civil War in 1856.

The Civil War saw substantial destruction of the U.S. commercial oceangoing fleet and there was a relative decline in the U.S. merchant marine fleet until World War I. At that time, much foreign flag service was withdrawn due to the war and there was a severe shortage of shipping. A shipping board was created in 1916 to reverse this trend. After World War I, subsidies were provided to shipyards and carriers for the construction and operation of U.S. flag vessels in foreign trade to avoid a repetition of the World War I crisis.

The major technical thrust in ocean shipping has been the continuing increase in size of vessels. High-speed container ships, and very large crude petroleum carriers and large dry bulk carriers have been constructed in recent years. Since the 1960s, containerization -- handling of a load of general cargo as a sealed unit rather than in individual pieces -- has had major impact on both the ships and the operation of ports. The economics of such operations have tended to concentrate cargoes at fewer and fewer ports where large container ships can operate economically. Likewise, large tankers can only be accommodated at a few selected ports where drafts are sufficiently deep. Thus, most of these tankers, when used for U.S. trade, have been unloaded offshore.

Specially designed ports for receiving oil off the Gulf Coast have been planned. Only one (the LOOP, off Louisiana) has gone into operation thus far. Large bulk carriers for ores and coal have been built up to 100,000 deadweight tons or more, requiring a 55-foot draft for efficient operation.

(b) Federal Costs for Oceans Ports and Channels

Table 8 shows the federal costs associated with the development and operation of the navigation systems supporting U.S. ocean ports.

TABLE 8

COASTAL PORTS AND DEEP DRAFT CHANNELS: FEDERAL COSTS EXPENDED BY CORPS
(ALL COSTS IN MILLIONS OF 1977 DOLLARS)

REGION	ESTIMATED REPLACEMENT COST(1)	ANNUAL DREDGING(2) VOLUME (1000 CU. YD.)	ANNUAL DREDGING(2) COST	ANNUAL OTHER OPERATIONS AND MAINTENANCE COST(2)	TOTAL OPERATIONS AND MAINTENANCE COST(2)
BATON ROUGE TO GULF	$ 441	58,542	$ 24.0	$ 3.8	$ 27.8
GULF COAST WEST	2,802	48,644	21.0	0.9	21.9
GULF COAST EAST	948	6,598	6.2	0.7	6.9
MOBILE RIVER AND TRIBUTARIES	122	4,025	2.1	0.9	3.0
SOUTH ATLANTIC COAST	2,499	22,440	10.7	3.4	14.1
MIDDLE ATLANTIC COAST	7,758	9,926	20.2	7.7	27.9
NORTH ATLANTIC COAST	3,099	822	2.5	0.3	2.8
WASHINGTON-OREGON COAST	1,038	6,784	5.8	1.1	6.9
COLUMBIA SNAKE	734	13,100	5.0	0.0	5.0
CALIFORNIA COAST	2,298	16,375	28.7	0.8	29.5
ALASKA	366	94	0.3	0.3	0.6
HAWAII AND PACIFIC TERRITORIES	371	152	0.2	0.0	0.2
CARIBBEAN	183	205	0.3	0.0	0.3
TOTAL	$22,659	187,707	$127.0	$19.9	$146.9

Notes: (1)Based on historical first costs adjusted for inflation.
(2)Annual average for 3 to 5 years ending 1977.

Source: Corps of Engineers, NWS Inventory.

Total estimated replacement cost of federal navigation improvements at U.S. coastal ports is estimated at over $22 billion. Dredging totals 188 million cubic yards per year at a cost of approximately $127 million. Other operations and maintenance costs are about $20 million per year, bringing the **total operating costs to approximately $147 million per year.**

(c) Characteristics of Coastal Ports

Table 9 shows principal characteristics and commerce of the 25 largest coastal ports in terms of annual tonnage handled.

TABLE 9

COASTAL PORTS AND CHANNELS: PRINCIPAL PORTS

REGION PORT	CONTROLLING DEPTH (FEET)	1977 COMMERCE IN MILLIONS OF TONS(1): FARM AND FOOD PRODUCTS	PETROLEUM(2)	COAL	METALS(3)	CHEMICALS/ FERTILIZER(4)	FOREST PRODUCTS	OTHER	TOTAL
BATON ROUGE TO GULF									
BATON ROUGE, LOUISIANA	40	11.5	31.1	0.0	9.4	15.3	0.4	2.3	70.0
NEW ORLEANS, LOUISIANA	40	67.4	59.0	9.5	7.2	12.2	1.5	6.2	163.0
GULF COAST WEST									
LAKE CHARLES, LOUISIANA	36	0.8	20.5	0.0	0.3	1.9	0.4	1.5	25.4
BEAUMONT, TEXAS	36	2.1	41.3	0.0	0.4	4.1	0.0	2.0	49.9
CORPUS CHRISTI, TEXAS	31	3.4	36.2	0.0	4.2	2.6	0.0	0.5	46.9
FREEPORT, TEXAS	33	0.1	11.3	0.0	0.0	3.7	0.0	0.2	15.3
HOUSTON, TEXAS	37	11.1	65.8	0.2	5.4	14.6	0.2	7.0	104.3
PORT ARTHUR, TEXAS	42	0.4	27.7	0.0	1.8	0.6	0.1	0.2	30.8
TEXAS CITY, TEXAS	40	0.0	26.8	0.0	0.0	6.8	0.0	0.0	33.6
GULF COAST EAST									
PASCAGOULA, MISSISSIPPI	38	2.5	18.8	0.0	0.3	1.6	0.1	0.5	23.8
TAMPA, FLORIDA	30(5)	1.2	11.5	2.8	0.6	28.1	0.1	1.5	45.6
MOBILE RIVER AND TRIBUTARIES	37-42	2.8	9.3	8.3	10.8	0.7	0.7	3.3	35.9
MIDDLE ATLANTIC COAST									
HAMPTON ROADS, VIRGINIA	35-45	6.6	12.5	26.6	0.6	1.6	0.4	4.1	52.4
BALTIMORE, MARYLAND	40	1.5	12.4	10.8	9.1	1.7	0.6	8.7	44.8
MARCUS HOOK, PENNSYLVANIA(6)	37		29.8	-	-	-	-	-	29.8
PHILADELPHIA, PENNSYLVANIA	37	3.4	37.7	0.6	5.1	1.0	0.2	1.7	49.7
PAULSBORO, NEW JERSEY(6)	37		27.0	-	-	-	-	-	27.0
NEW YORK, NEW YORK	30-45	6.8	148.5	0.9	2.7	5.4	1.3	19.7	185.3
NORTH ATLANTIC COAST									
BOSTON, MASSACHUSETTS	35-38	0.7	23.6	0.0	0.2	0.1	0.1	1.3	26.0
PORTLAND, MAINE	35-45	0.0	18.3	0.0	0.0	0.0	0.0	0.0	18.3
WASHINGTON OREGON COAST									
SEATTLE, WASHINGTON	33	1.7	4.5	0.0	0.9	0.8	2.8	5.8	16.4
COLUMBIA-SNAKE									
PORTLAND, OREGON	40	6.4	5.8	0.0	0.6	0.6	4.2	3.8	21.4
CALIFORNIA COAST									
LONG BEACH, CALIFORNIA	50-55	1.6	23.0	0.0	4.5	1.0	0.8	2.1	33.0
LOS ANGELES, CALIFORNIA	35-52	0.8	22.8	0.0	1.9	0.9	0.6	4.3	31.3
RICHMOND, CALIFORNIA	17-34	0.1	22.2	0.0	0.2	0.5	0.0	0.8	23.8

Notes: (1) Includes all domestic (internal, local and coastwise) and foreign traffic.
(2) Crude petroleum and petroleum products.
(3) Metallic ores and primary metal products defined in Exhibit II plus limestone.
(4) Includes sulfur and phosphate rock.
(5) A deepening project is under way at this time. Greater depths, up to 44' are available in some channels at this time.
(6) No breakdown of traffic was available for the ports, but the principal commodities include petroleum and petroleum products.

Source: Corps of Engineers, _Waterborne Commerce of the United States_, 1977.

The ports range from a controlling draft of 31 feet at Corpus Christi to as much as 55 feet at Long Beach, California. Ocean port tonnages are dominated by the movement of imported crude petroleum to U.S. refineries and distribution of petroleum products to consuming areas. Other major bulk commodity cargoes include export food and farm products (mostly grain), industrial chemicals and fertilizers (such as phosphate rock), coal and ores. In addition, these major ports handle substantial quantities of general cargo, including iron and steel products, machinery of all kinds, and transportation equipment.

Exports of farm products are concentrated in the Gulf as are shipments and receipts of industrial chemicals and fertilizers. Coal export shipments are made predominantly from the East Coast. There is also a substantial domestic movement of coal from New Orleans and Mobile to Florida utilities and from Mobile for export. Forest products traffic is concentrated along the Pacific Northwest.

SUMMARY

There has been a long federal involvement in the development and maintenance of the nation's navigation system. The navigation system, in turn, has played a key role in the development of the nation. Table 10 summarizes the federal investment and annual operating cost of the national navigation system.

TABLE 10

FEDERAL COSTS FOR THE NATIONAL NAVIGATION SYSTEM EXPENDED BY CORPS OF ENGINEERS
(ALL COSTS IN MILLIONS OF 1977 DOLLARS)

AREA	ESTIMATED REPLACEMENT COST(1)	ANNUAL DREDGING(2) VOLUME (1000 CU. YD.)	ANNUAL DREDGING(2) COST	ANNUAL OTHER OPERATIONS AND MAINTENANCE COST(2)	TOTAL ANNUAL OPERATIONS AND MAINTENANCE COST(2)
SHALLOW DRAFT WATERWAYS	$24,386	94,116	$ 49.9	$ 96.6	$146.5
GREAT LAKES AND ST. LAWRENCE SEAWAY	4,837	7,009	15.2	9.3	24.5
COASTAL PORTS AND CHANNELS	22,659	187,706	127.0	19.9	146.9
TOTAL	$51,882	288,832	$192.1	$125.8	$317.9

Notes: (1)Based on historical first costs adjusted for inflation.
(2)Annual Average for 3 to 5 years ending 1977.

Source: Corps of Engineers, NWS Inventory.

Total estimated investment in the navigation system in 1977 dollars is nearly $52 billion with nearly equal amounts invested in the shallow draft inland waterways system and the deep draft coastal ports. Annual dredging volume is 288 million cubic yards of which nearly two-thirds is devoted to dredging of deep draft coastal ports. Total annual operating costs for dredging, lock operation, and other maintenance of the navigation system is approximately $318 million. Approximately equal amounts are devoted to operation of inland waterways and coastal ports.

In addition to expenditures handled by the Corps of Engineers, approximately $15 million per year is spent by the State of New York maintaining and operating the New York State Barge Canal and $5 million per year is spent by the Seaway Development Corporation (recovered from tolls). Additional expenditures have been made by the Coast Guard for commercial navigation but are included with costs for other programs and cannot be isolated. Total Coast Guard budget in 1978 was $924 million, some portion of which benefited commercial water transportation users.

III - DESCRIPTION OF NAVIGATION SYSTEM USERS

This section will describe the logistics process of the six major industries that contribute the vast majority of waterborne cargoes. They are: agriculture, petroleum, coal, metals, chemicals/fertilizer, and forest products. For each, there is a description of the industry producers and consumers, the principal commodities involved, a description of the decisionmaking that drives the logistics process in that industry, a description of historic cargo flows, and conclusions that affect the future use of the navigation system. A summary of major conclusions is presented at the end of the section.

AGRICULTURE

Agricultural products of particular interest for an analysis of waterborne commerce include grains (wheat, corn, and soybeans) mostly produced in the Midwest, grain mill products (primarily animal feed) and vegetable oils (e.g., soybean oil). Although cotton was once a significant commodity on southern rivers, very little cotton is handled on inland waterways today. Most other food and farm products are either too valuable or time sensitive for relatively slow domestic movement by water. However, a wide range of food and farm products in addition to the above are handled in import/export trade. These include imports of coffee, sugar, cocoa, and bananas, and the export of packaged food products.

About two percent of the nation's population lives on farms. Acreage for corn, wheat, and soybeans alone, however, makes up 10% of the total land mass of the country. Grain is typically trucked from individual farms to thousands of local grain elevators serving them. From there, grain is shipped either to one of approximately 40 regional grain merchandising companies or to one of a handful of large integrated international grain exporters (such as Continental Grain, Cargill, Louis Dreyfus, Farmers Export, or Bunge). As an alternative, the grain may be processed by a feed producer (such as Ralston Purina, Central Soya, or ConAgra), by a wheat miller for domestic consumption (Pillsbury, Archer-Daniels-Midland, or Peavey), or by a grain processor (such as CPC or A. E. Staley Manufacturing) to convert to oils, starches, sugars and other products.

Domestically, grain products are consumed directly and grain is fed extensively to livestock to produce meat. The domestic market tends to be very stable and is growing modestly but steadily from year to year. The key market that affects future trends in

U.S. agriculture, however, is the export market. Worldwide, population is growing and real income is increasing. Thus, the world market for grain is growing more rapidly than the domestic U.S. market. Exports of grain are made to Europe, Japan, China, Russia, and India -- all of which are net importers of grain products on a regular basis. The United States supplies approximately 40% of all world exports of wheat (Canada and Australia being other major exporters). The U.S. supplies over half of all world corn exports (Argentina and South Africa being other major producers) and over 65% of all soybean exports (Brazil being the other major exporter). **The total value of U.S. farm exports in 1977 was over $24 billion or about 20% of all U.S. exports.**

The export grain market can be characterized as volatile and very price sensitive. Each year, there is uncertainty about the size of the crop that will be produced in each of the major producing countries (primarily because of the weather). Therefore, some inventory is carried over from season to season on farms, in country elevators, and in terminal storage. The timing of the release of that grain into the market can have a major effect on the world price of that grain product. For instance, the 1972 Russian wheat sale was negotiated primarily between the two governments without public disclosure. The price of wheat on world markets was approximately $2 per bushel. As soon as the "deal" was announced, the world price of wheat began to rise and over the succeeding two years rose to nearly $6 per bushel. Therefore, the worldwide forces of supply and demand, and the astute timing of grain release by the American farmer, produces an intriguing competitive environment in the grain industry.

Grain exports are highly competitive. As little as a penny a bushel difference in the delivered price of grain in Rotterdam (the basing point for pricing in Europe) can have a major impact on the competitiveness of U.S. grain in export markets. To gain some understanding of the importance of the transportation component in this pricing, a "typical" bushel of grain from farm to delivery in Rotterdam will be traced. The farmer might receive $3 for his bushel of grain at his farm. It costs about $.05 to truck it to a local elevator and there is usually about a $.10 handling, storage, and drying charge at the local county elevator. It might cost another $.05 to truck the grain to a barge (or rail) loading terminal and another $.02 to load it into the barge or train. The barge freight to New Orleans might be $.40 and it might cost an additional $.10 for elevating and handling in New Orleans. Ocean freight might add another $.40, bringing the total delivered price to $4.12 in Rotterdam. **Thus approximately a**

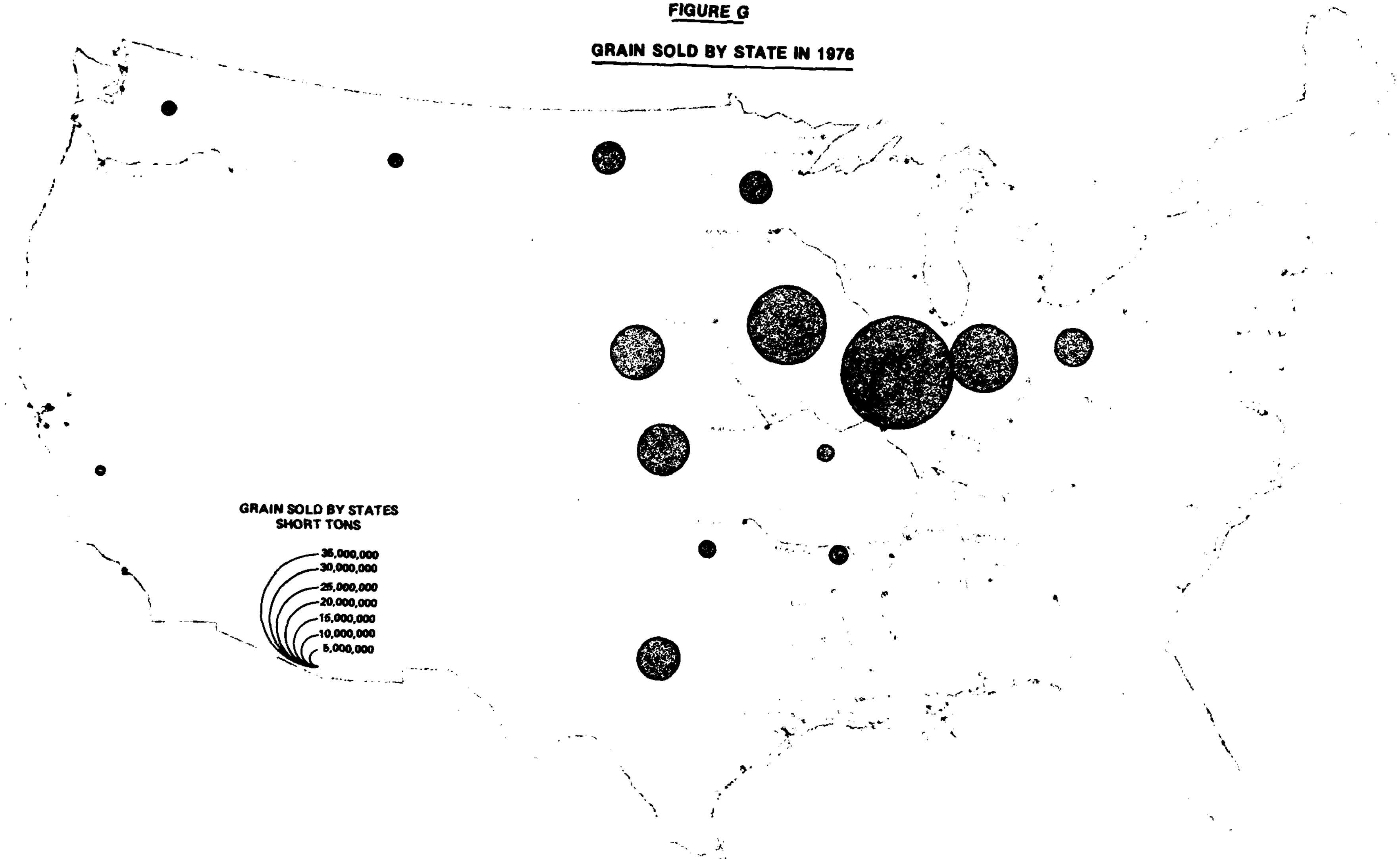
quarter of the total delivered price of the grain is consumed by the logistics process.

If there were a direct rail alternative, the rail freight might cost $.50 (versus the $.40 for barge freight) adding a full dime to the delivered cost and making the grain less competitive in world markets. However, alternative routings are not common. Grain which is produced within "reach" of the river will typically move to the river for barge transportation downbound to New Orleans. Grain which is beyond the economic "reach" of the river (in this case, grain located at points with more than a $.10 differential in favor of shipping to a rail versus barge loading station) will be moved in rail unit trains to other Gulf coast ports (e.g., Houston) or to Great Lakes, Atlantic, or Pacific ports. This logistics system is finely tuned to the existing economics of the barge and rail industries and massive fixed investments have been made along the rivers, in unit train elevators, and in ocean and lake ports to support this logistics process. Therefore, there will be strong resistance from the agricultural industry to any disruption of the grain logistics system.

Figure G on the following page shows the source of domestic grain production which is sold as a cash crop. Clearly, Illinois, Iowa, and Indiana are the three largest producers - all of them adjacent to the river and Great Lakes for transportation.

FIGURE G

GRAIN SOLD BY STATE IN 1976



Source: Corps of Engineers, Waterways System and Commodity Movement Maps.

Table 11 shows the cargo tonnages of agricultural products for each of the major product groups that are handled on shallow draft waterways, on the Great Lakes and coasts for domestic movement, and in foreign commerce both via the Great Lakes and ocean ports.

TABLE 11

AGRICULTURE: 1977 WATERBORNE COMMERCE
(MILLIONS OF SHORT TONS)

COMMODITY	DOMESTIC(1) SHALLOW DRAFT(2)	GREAT LAKES	COASTS	FOREIGN	TOTAL
CORN	23.2	0.0	0.4	44.2	67.8
WHEAT	10.1	1.4	0.3	26.3	38.1
SOYBEANS	11.7	0.0	0.0	17.8	29.5
VEGETABLE OILS	1.1	0.0	0.1	2.4	3.6
GRAIN MILL PRODUCTS	6.2	0.2	0.5	9.6	16.5
OTHER	4.4	0.2	5.2	37.0	.8
TOTAL	56.7	1.8	6.5	137.3	202.3

Notes: (1)A large proportion of the shallow draft traffic was shipped to Gulf Coast elevators for export. Waterborne Commerce counts such barge-to-vessel shipments as both domestic and foreign movements.
(2)Includes local traffic within ports.

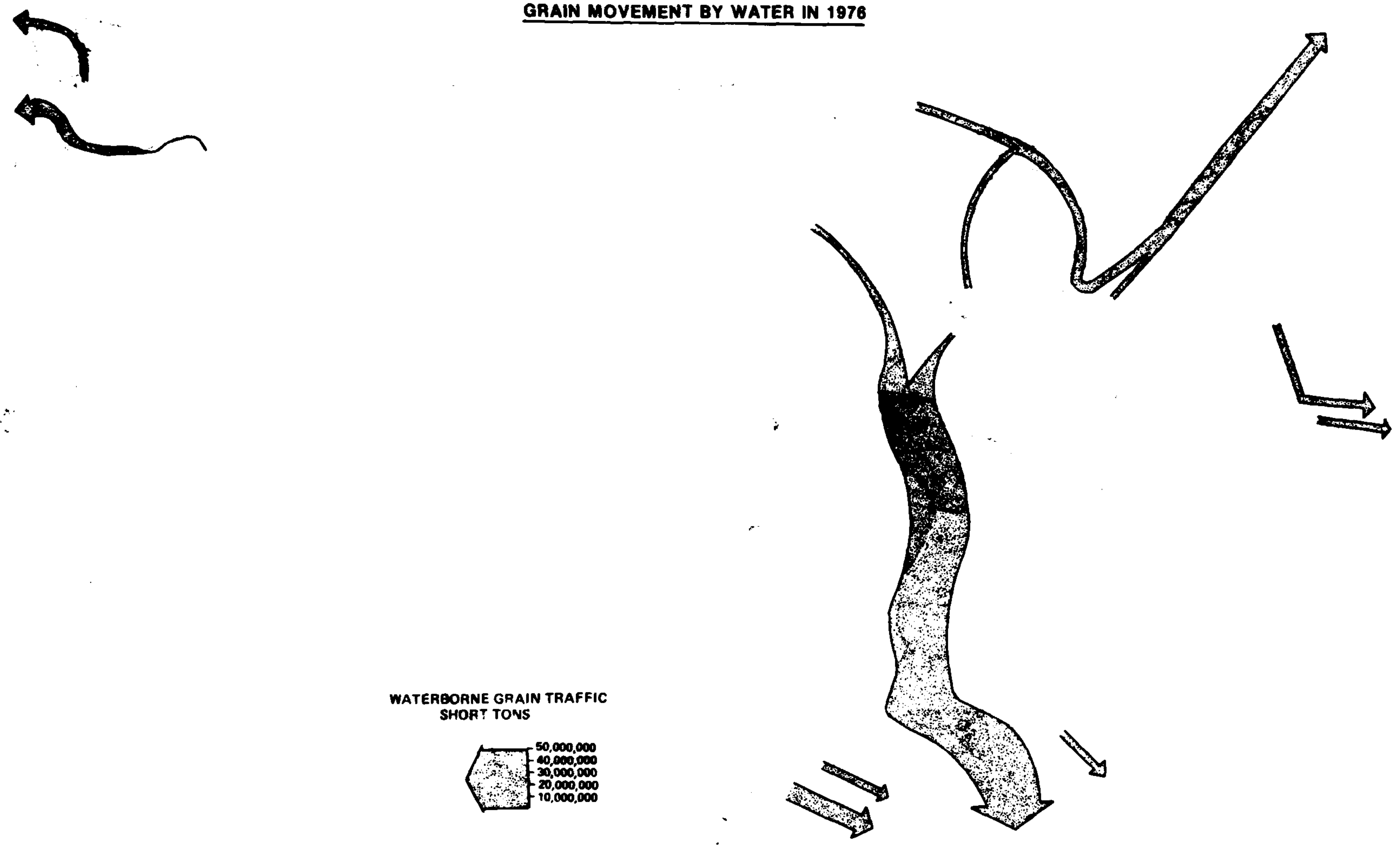
Source: U.S Corps of Engineers, Waterborne Commerce of the United States, 1977.

Nearly 57 million tons of agricultural products were moved on the shallow draft waterways in 1977. In contrast, about 2 million tons were handled domestically on the Great Lakes and about 6.5 million tons were handled in domestic ocean transport. Domestic ocean trade consisted primarily of foodstuffs moving to and from Alaska, Puerto Rico, Hawaii and the contiguous 48 states. Over 137 million tons were handled in import and export trade with about 60% handled by Gulf Coast ports, 15% by West Coast ports, and the balance evenly divided between the Great Lakes/St. Lawrence Seaway and the Atlantic Coast.

Grain traffic, the dominant flow, can be seen clearly in Figure H on the next page. The vast majority of the domestic grain movement flows down the Mississippi and Illinois Rivers to New Orleans for export. Galveston and Houston in Texas, Portland in Oregon, Chicago and Duluth on the Lakes, and Baltimore and Hampton Roads on the East Coast handle the remainder of the tonnage.

FIGURE H

GRAIN MOVEMENT BY WATER IN 1976



Source: Corps of Engineers, Waterways System and Commodity Movement Maps.

The shallow draft waterways and the ports are critical to the competitiveness of U.S. agriculture in world markets. These exports, in turn, are an important component of the U.S. balance of payments needed to finance our continuing purchase of foreign petroleum. Therefore, a healthy and productive waterway system has a national importance far beyond just the individual states and ports involved in agricultural and grain transportation.

PETROLEUM

To understand the petroleum logistics process, one must understand the sources of crude oil, the location and use of refining capacity, and the petroleum marketing process.

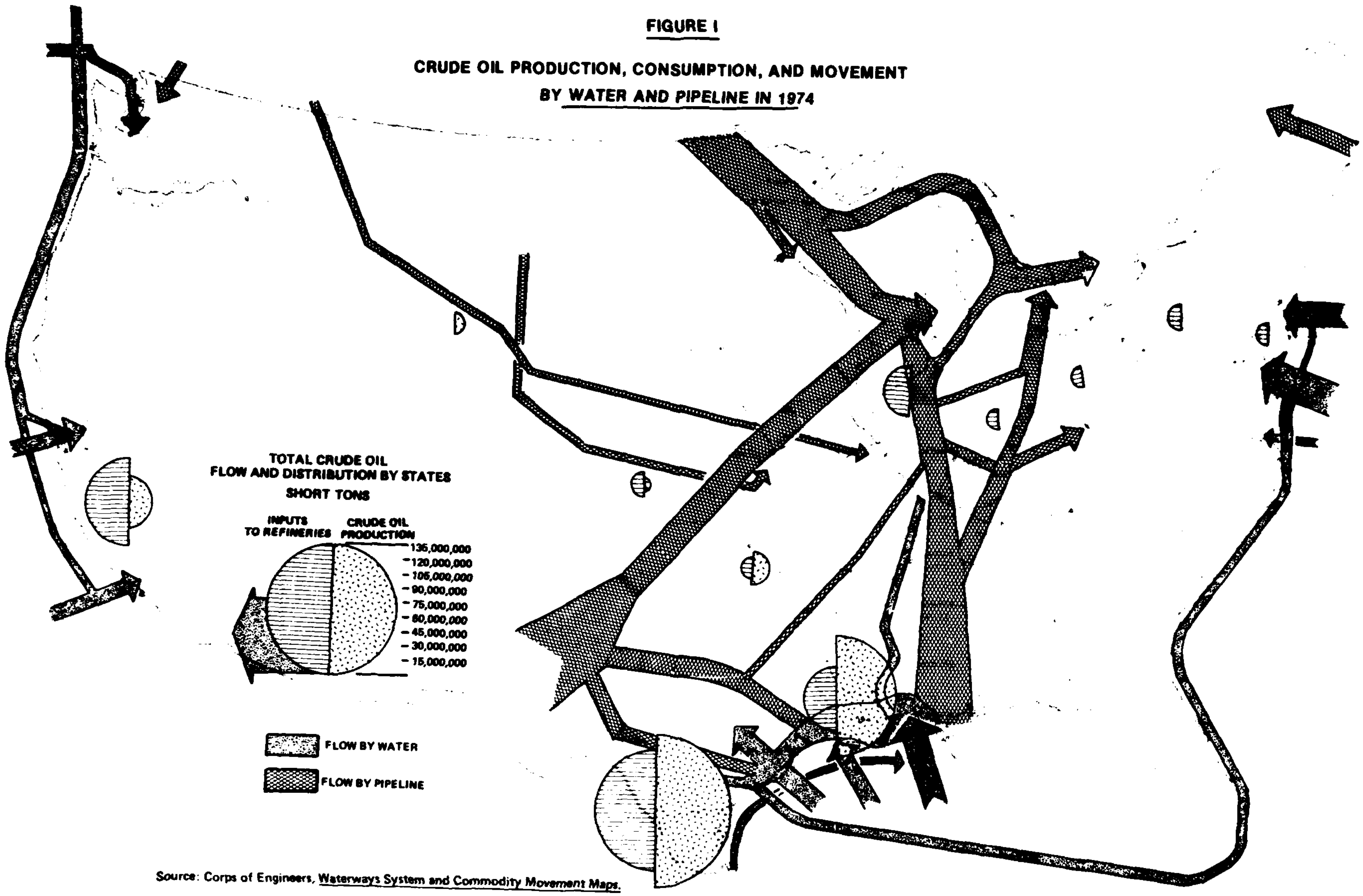
Crude oil is produced both domestically and from overseas sources. Domestic production meets approximately half of domestic needs. Major petroleum producing states are Texas, Louisiana, Alaska, and California, together accounting for approximately 80% of domestic production. Imported oil comes from a wide range of origins around the globe. In descending order of exports to the U.S., the countries are Saudi Arabia, Nigeria, Libya, Algeria, Iran (in 1977), and Indonesia. Together, these countries account for over 70% of imported crude. Figure I shows domestic crude oil production, ports of entry for foreign crude, and domestic refining levels by state.

In addition to being points of domestic production of crude, both Texas and Louisiana are major ports of entry for foreign crude and, between them, contain approximately two-thirds of domestic refining capacity. Other major refining capacity is found in California, Illinois and, to a lesser extent, in Indiana, Ohio, and Pennsylvania. In addition, significant imports of crude petroleum are landed in the Delaware Bay (Philadelphia area) and New Jersey for nearby refining.

Refineries are operated by the major integrated international oil companies (Exxon, Texaco, Mobil, Gulf, Chevron, BP, and Shell) as well as by integrated domestic producers (such as Amoco and Phillips). Major independent refiners include Clark Oil, Ashland, and others. Refineries are complex and expensive capital investments that require a steady flow of crude oil and a high utilization to be profitable.

FIGURE I

CRUDE OIL PRODUCTION, CONSUMPTION, AND MOVEMENT
BY WATER AND PIPELINE IN 1974



Source: Corps of Engineers, Waterways System and Commodity Movement Maps.

The major products produced by refineries include gasoline (50%) for automobiles, jet fuel and kerosene (8%) mostly for aviation fuel, distillate fuel oil for heating and diesel transportation (21%), and residual fuel oil (11%) used as boiler fuel. Table 12 shows the 1977 tonnages of each of these commodities handled by water.

TABLE 12

PETROLEUM: 1977 WATERBORNE COMMERCE
(MILLIONS OF SHORT TONS)

COMMODITY	DOMESTIC SHALLOW DRAFT(1)	DOMESTIC GREAT LAKES	DOMESTIC COASTS	FOREIGN	TOTAL
CRUDE PETROLEUM	54.1	0.0	30.7	403.9	488.7
GASOLINE	39.3	1.4	54.2	3.6	98.5
JET FUEL AND KEROSENE	8.0	0.2	9.9	3.2	21.3
DISTILLATE	42.0	1.6	46.0	7.9	97.5
RESIDUAL	78.6	1.8	53.6	68.5	202.5
OTHER(2)	13.3	0.4	10.9	25.4	50.0
TOTAL	235.3	5.4	205.3	512.5	958.5

Notes: (1) Includes the local traffic within ports.
(2) Includes asphalt, the majority of foreign coke (produced from coal and petroleum) traffic classified under primary metal products in Waterborne Commerce of the United States, and other miscellaneous petroleum products.

Source: U.S Corps of Engineers, Waterborne Commerce of the United States, 1977.

Note that crude petroleum makes up over half of this industry's waterborne tonnage, most of which is from imports. Gasoline is distributed by barge and by coastal tanker (mainly from the Gulf Coast to the East Coast). Jet fuel, kerosene and distillate all move in similar distribution patterns to tank farms near the final consumption point. Residual fuel oil moves mostly by barge and tanker directly to power plants for use as boiler fuel. A great portion of the imported residual comes from Caribbean refineries directly to power plants.

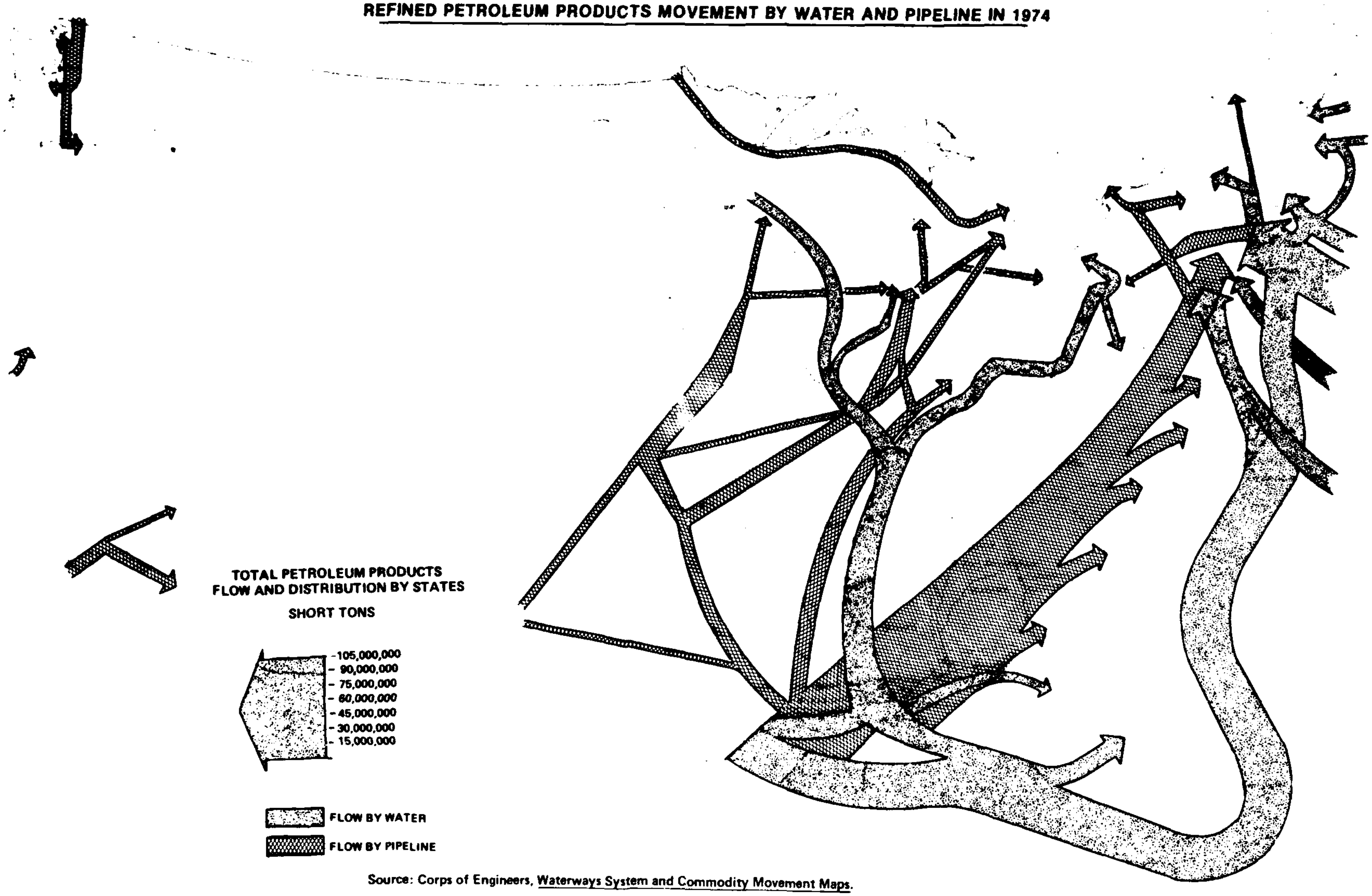
Far more important than water transportation for all of these products (except residual which is very viscous) is pipeline transportation. In comparison to the 446 million tons of crude petroleum and petroleum products handled domestically by water, pipelines handled 1.8 billion tons in 1977. The reason is that, once pipelines are constructed, the variable cost of operation is far lower than for water transportation. Therefore, stable petroleum flows move via pipeline in volumes limited only by demand and the practical capacity of a pipeline. Only short-haul distribution (where no pipeline exists) and long-haul flows beyond pipeline capacity move via water.

Petroleum product flows by water and pipeline are shown in Figure J on the following page. Note the substantial movement by both pipeline and water from the Gulf Coast to the populous East Coast states as well as up the Mississippi River to the industrial Midwest. Most distribution through the Plains states is by pipeline. Final distribution of petroleum products from tank farms to service stations and home and industrial users is by truck. Virtually no crude oil or significant volume of petroleum products moves by rail.

Water transportation of crude oil and petroleum products is pervasive. The vast majority of all coastal traffic and the major commodity in most coastal ports is petroleum. Therefore, the maintenance of adequate capability of coastal ports and channels is important to the petroleum distribution system.

FIGURE J

REFINED PETROLEUM PRODUCTS MOVEMENT BY WATER AND PIPELINE IN 1974



Source: Corps of Engineers, Waterways System and Commodity Movement Maps.

COAL

Coal is mined domestically from nearly 6,000 individual mines. About two-thirds of total production comes from the 50 largest coal mining companies. Therefore, the coal mining industry is relatively fragmented, although recent purchases by major energy companies may result in greater concentration in the years ahead. Domestic coal deposits are shown in Figure K on the following page.

The major sources of metallurgical coal for steel making are found primarily in West Virginia, western Pennsylvania and eastern Kentucky. High BTU steam coal (for burning in power plants) is found in Pennsylvania, West Virginia, Virginia, and Kentucky. Medium BTU (but high sulfur) coal is found in Illinois, Indiana, Ohio, and western Kentucky. Low sulfur (but also low BTU content) coal is found in the western states of Montana, Wyoming, and Colorado. Large deposits of low quality coal and/or lignite are found in Texas, Kansas, Missouri, and North Dakota, but these are not economic to transport any significant distance.

The major consumers of coal are electric utilities with coal-fired power generating plants. A secondary and growing market is international coal export to Europe and Japan. Until recently, these exports have been to foreign steel making companies; but, in the last two years, the U.S. has become a major exporter of steam coal to overseas destinations for power generation.

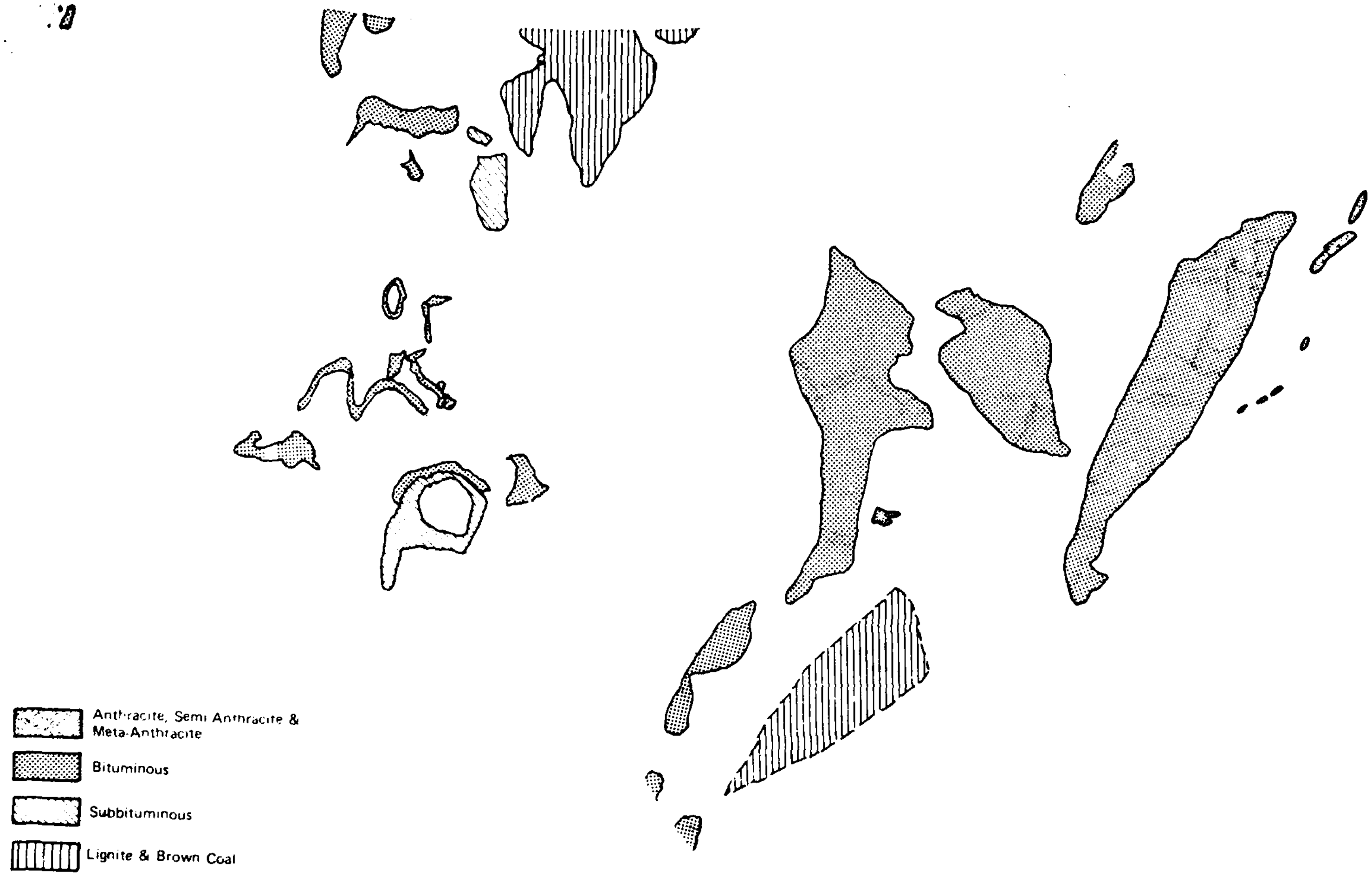
Metallurgical coal is used primarily by the steel industry with major plants around the Great Lakes, in the mid-Atlantic coast and in Alabama. Further discussion of this industry appears later in this section.

Because of the rapidly rising price and concern about the reliability of supply of petroleum, a significant shift away from petroleum (and natural gas) for boiler fuel and power generation is in process. Some of that slack will be absorbed by increased use of nuclear power but much of it will be taken up by coal at least for the remainder of this century.

An additional factor in the coal logistics system is the standard for environmental emissions, which often requires the consumption of relatively low sulfur coal. Although some relaxing of these regulations may occur, many power plants have turned to lower BTU

FIGURE K

DOMESTIC COAL FIELDS OF KNOWN COMMERCIAL VALUE



Source: McGraw Hill Inc., Keystone Coal Industry Manual, 1979.

coal from western states (moving by rail to the East) rather than to nearby reserves of higher sulfur coal. Thus, the coal logistics system is no longer characterized by flows from nearby mines to power plants but is now becoming characterized by more complicated long-distance coal transportation systems.

Once a power plant is built, the commitment of investment, the design of the power generating system itself (e.g., committed to burning coal with particular BTU and sulfur content) plus long-term contracts for coal supply and transportation often eliminate logistics options. Therefore, the key coal logistics decisions are often made prior to the construction of a new power plant.

A typical sequence of decisionmaking for the construction of a new coal-fired power plant might be as follows:

- Size the plant for the expected power demand of the consuming area.

- Select the fuel to be used (e.g., oil, gas, nuclear. or coal) and, if coal, the specific mixtures required to meet environmental requirements at minimum overall design cost. Thus, a mixture of coal is often required to achieve a particular BTU and sulfur content.

- Locate a number of alternative sources of coal (each with unique properties) which might potentially be burned to fuel the power plant.

- Select a number of alternative potential sites for the power plant (mine mouth, urban or rural, adjacent to a waterway, etc.).

- Identify alternative transportation routings and modal combinations from each coal source to each power plant.

- Analyze the alternative systems including price and quality of coal, transportation costs and long-term reliability, and alternative sites, to establish priorities for the alternatives.

- Negotiate long-term contracts for coal supply, transportation, and site acquisition before committing to plant construction.

Note that the transportation and logistics decisions are integral to the total capital investment decision and that long-term reliability of transportation is an important consideration when making a 30-to 50-year power plant investment commitment.

Table 13 shows the 1977 waterborne tonnage for coal.

TABLE 13

COAL: 1977 WATERBORNE COMMERCE
(MILLIONS OF SHORT TONS)

COMMODITY	DOMESTIC SHALLOW DRAFT(1)	DOMESTIC GREAT LAKES	DOMESTIC COASTS	FOREIGN	TOTAL
Coal	130.4	22.2	3.7	55.5	211.8

Note: (1) Includes local traffic within ports.

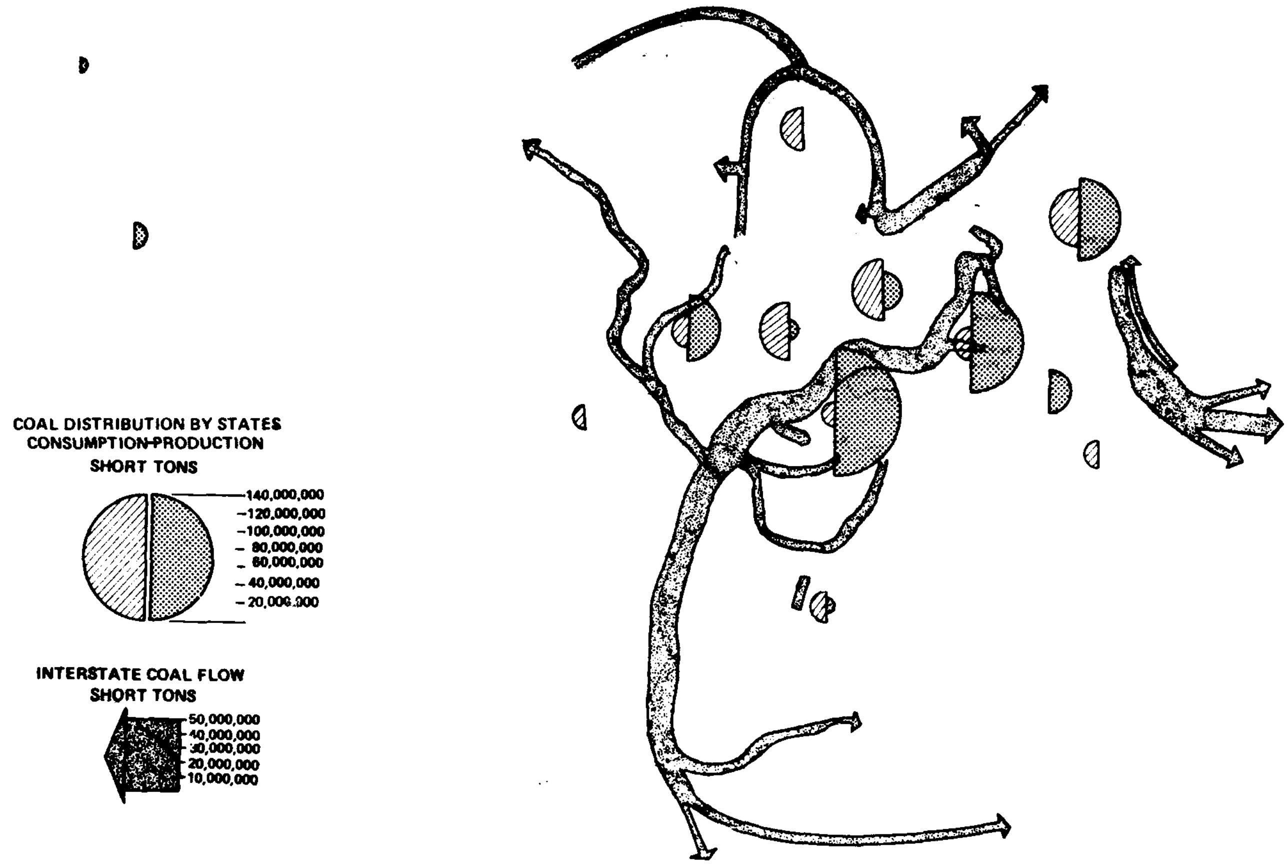
Source: U.S Corps of Engineers, Waterborne Commerce of the United States, 1977.

Note that the vast majority of coal was handled by shallow draft waterways with smaller amounts by the Great Lakes and on foreign trade routes. The foreign traffic includes exports to Canada and overseas destinations for both steel making and steam generation.

Figure L shows these flows graphically for the waterways and ports. Note that there are heavy inland flows along the Ohio River between the eastern coal fields and midwestern power plants. There are also significant flows down the Mississippi for consumption by southern utilities, transloading for Florida and for export. Upbound flows have traditionally moved on the Upper Mississippi to Minneapolis and the Illinois to Chicago. Newer western coal flows are moving down the Upper Mississippi, reversing the traditional direction of flow. Major export flows to Europe and Asia are handled principally from Hampton Roads, Virginia, and Baltimore, Maryland.

FIGURE L

COAL PRODUCTION, CONSUMPTION, AND MOVEMENT BY WATER IN 1974



Source: Corps of Engineers, Waterways System and Commodity Movement Maps.

Several major forces are at work which will affect coal transportation. Besides the shift towards western coal (which will rapidly increase rail ton-miles of coal transportation), slurry pipelines, increased coal exports, and the opening of the Tennessee-Tombigbee waterway will have impacts.

Seven proposals for major coal slurry pipelines are actively being considered. Such pipelines tend to have better long-term economics than rail transportation -- primarily because pipeline costs are less subject to inflation. Inflating labor and fuel costs are a small component of the pipeline total, compared with railroads and barges. The problems associated with construction of these pipelines are primarily related to a sufficient water supply to use as the slurry medium and to the vehement opposition of the railroads, across whose right-of-way such pipelines must be built. Therefore, whether additional slurry pipelines will actually be constructed or not depends heavily on institutional and political factors yet to be resolved. However, the seven proposed pipelines would serve primarily to carry increased new tonnages of coal or divert existing rail traffic and would have little overall impact on domestic <u>waterborne</u> coal traffic.

Rapidly increasing exports of coal to Europe and Asia for power generation have taxed the existing ocean port loading facilities. Most of the congestion has related to the shoreside loading facilities. Expansion plans already announced should be sufficient to relieve these export constraints in the coming years. There have also been requests by coal exporting companies and foreign users for deeper channels to and from key coal loading ports to allow the use of more efficient 100,000 deadweight ton (DWT) vessels or larger. Hampton Roads, Mobile, and New Orleans are often mentioned as candidate ports for deepening to 55 feet.

The connection of the Tennessee and Tombigbee waterways allows a far more direct route for eastern mountain-states coal to move to the Gulf Coast for export. Therefore, the opening of the Tennessee-Tombigbee waterway (currently scheduled for 1986) may result in stimulated coal flows to Gulf Coast ports.

Coal and its efficient logistics are critical to the health of the nation's economy through the end of this century. Coal will be the dominant fuel for domestic power generation for the foreseeable future. Coal exports will generate substantial trade revenues to help pay for the continued imports of petroleum. Further, exports to other free world countries help to reduce their dependence on unstable and high priced alternative sources of energy -- both petroleum and coal from other sources. Therefore, an adequate and reliable water transportation system for both domestic and foreign movement of coal is critical to the national interest.

METALS

The metals group includes primarily the steel and aluminum industries. Other metal industries, such as copper and lead, do not generally use water transportation due to the geographic location of domestic mining operations.

The steel industry involves four major production stages - iron ore mining, pig iron production, steel making, and steel rolling. The major companies are vertically integrated to perform all of these functions. They include U.S. Steel, Bethlehem, Republic and Inland. Together, the major integrated producers account for the vast majority of U.S. steel production (along with the auto manufacturers who make some of their own steel).

Steel production requires iron ore, limestone, steel scrap, coke (from coal or petroleum) and smaller amounts of alloying minerals. The result is steel mill products such as girders, bars, rods, plates, rolls, etc.

The logistics process for all of the high volume movements is very finely tuned to produce a reliable low cost flow of material to keep the capital-intensive, steel making plants producing at the desired capacity. Thus, the integrated steel making companies control the iron ore, limestone, and coal mining operations, the rail link to a Great Lakes port, the loading operation, the Great Lakes shipping of each of these raw materials, the transloading, and the rail movement into the plant, if that is needed. **Because the system is finely tuned and massive capital investment has been integrated with a logistics system, there is very little likelihood of significant change in the logistics system of the steel industry.**

The aluminum industry also involves four major production stages - bauxite mining and milling, alumina refining (bauxite is processed electrolytically into alumina), aluminum reduction (alumina is chemically reduced to calcined aluminum metal and then molten aluminum), and fabrication. The U.S. is not a large producer of bauxite, but is the world's largest producer of aluminum. **Accordingly, the U.S. must import bauxite and alumina depending heavily on efficient ocean ports and waterways for delivery to producing plants.** Primary sources are Australia, Guinea, Jamaica, and Brazil.

Table 14 shows the waterborne movement of steel raw materials and products in 1977 as well as the movements of other ores, principally imports of aluminum ores to the U.S. aluminum production plants.

TABLE 14

METALS: 1977 WATERBORNE COMMERCE
(MILLIONS OF SHORT TONS)

	DOMESTIC				
COMMODITY	SHALLOW DRAFT(1)	GREAT LAKES	COASTS	FOREIGN	TOTAL
IRON ORE	5.7	44.3	0.0	42.3	92.3
OTHER ORES	2.3	0.0	0.0	20.7	23.0
LIMESTONE	1.7	26.9	0.0	10.5	39.1
COKE (2)	0.0	0.0	0.0	2.8	2.8
IRON AND STEEL PRIMARY FORMS	0.6	0.0	0.0	0.5	1.1
STEEL MILL PRODUCTS	5.1	0.1	0.3	17.7	23.2
PRIMARY METALS	2.2	0.5	0.3	4.2	7.2
TOTAL	17.6	71.8	0.6	98.7	188.7

Notes: (1) Includes local traffic within ports.
(2) Domestic shipments are included in coal. Foreign shipments as reported in Waterborne Commerce of the United States are included there.

Source: U.S Corps of Engineers, Waterborne Commerce of the United States, 1977.

Iron ore is moved into steel plants primarily by bulk carrier either from the domestic or Canadian mines adjacent to the Great Lakes. More than 92 million tons were handled in 1977. Limestone totaled more than 39 million tons, also by lakes from domestic or Canadian sources. Coke movements for steel making, are included in the data collected by the Corps of Engineers for coal and are discussed there. Most coke, however, is produced at or near the steel making facilities. Movements of finished and semifinished metal products by water total more than 30 million tons, mostly shallow draft and imports.

The iron ore flows are shown in Figure M on the following page. The dominance of the movements from Canadian and U.S. sources via the Great Lakes to the steel mills adjacent to the Lakes in Illinois, Indiana, Ohio, and Pennsylvania is very clear.

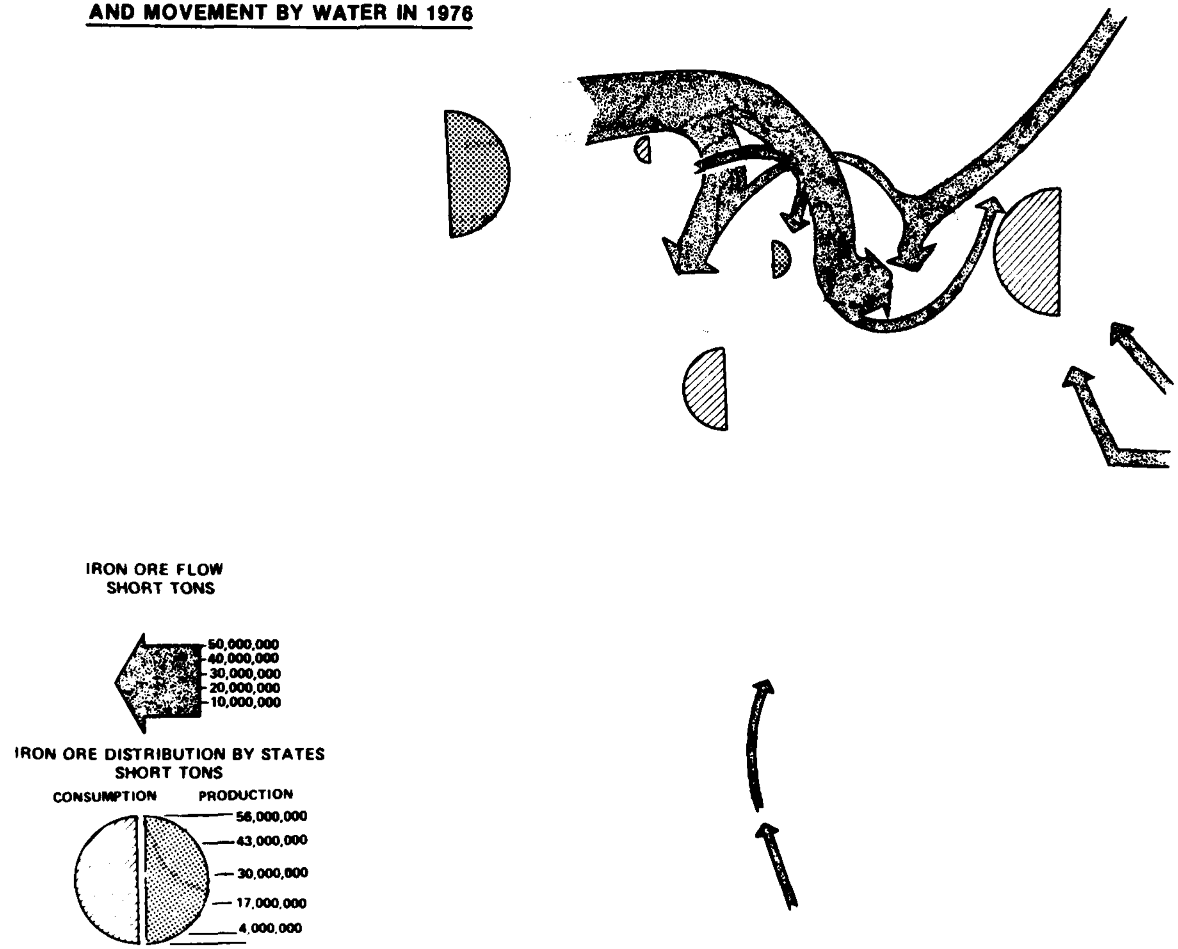
Bauxite and/or alumina is moved in deep-draft vessels principally to Gulf ports. From there, the ores are shipped by rail (and to a much smaller degree barge) to processing plants in the Southwest, the Pacific Northwest, and the Midwest.

It should be noted that the geographically concentrated steel industry plays a major role in the defense of the nation. Military conflict requires vast amounts of steel production for ships, vehicles, and other weapons. **Thus, the reliability of the logistics system to support the steel making industry, and adequate capacity to adapt to a national emergency, are important considerations of national importance.**

In recent years, foreign steel producers have captured an increasing share of the U.S. steel market, resulting in a reduction of domestic steel making capacity. In a major national emergency, these foreign sources of steel might well become unavailable, placing a major burden on the domestic steel makers and their logistics systems.

FIGURE M

IRON ORE PRODUCTION, CONSUMPTION, AND MOVEMENT BY WATER IN 1976



Source: Corps of Engineers, Waterways System and Commodity Movement Maps.

CHEMICALS/ FERTILIZER

The industrial chemical industry is different from all of the other industries discussed thus far. It is an industry with a number of major producers: Dupont, Union Carbide, Dow, Allied, and many of the petroleum companies. It is an industry characterized by high research and development investment in new products, high investment in process chemical plants, and a high rate of capital obsolescence, as new processes and products are discovered. The product line is rapidly expanding with more and more chemicals available, many of them shipped in relatively small lots (compared to grain, petroleum, and coal) to industrial customers. Generally, chemicals are more valuable per pound than any other products discussed in this section.

As a result, water transportation handles only about one quarter of all basic and intermediate industrial chemical shipments and is not important in the distribution of finished chemical products. Rail and truck modes handle the remaining traffic. Waterborne tonnages are shown in Table 15.

TABLE 15

CHEMICALS/FERTILIZER: 1977 WATERBORNE COMMERCE (MILLIONS OF SHORT TONS)

COMMODITY	DOMESTIC SHALLOW DRAFT(1)	DOMESTIC GREAT LAKES	DOMESTIC COASTS	FOREIGN	TOTAL
SULFUR	4.5	0.0	3.9	2.3	10.7
SODIUM HYDROXIDE	4.0	0.0	1.4	0.0	5.4
CRUDE TAR OIL AND GAS PRODUCTS	1.7	0.0	0.5	0.5	2.7
ALCOHOLS	2.4	0.0	1.8	0.0	4.2
BENZENE AND TOLUENE	3.7	0.1	0.8	0.0	4.6
SULFURIC ACID	2.5	0.0	0.1	0.0	2.6
PHOSPHATE ROCK	1.0	0.0	8.6	14.5	24.1
NITROGENOUS CHEMICAL FERTILIZERS	3.0	0.0	0.4	1.2	4.6
POTASSIC CHEMICAL FERTILIZERS	0.3	0.1	0.1	1.6	2.1
PHOSPHATIC CHEMICAL FERTILIZERS	0.5	0.0	0.1	1.3	1.9
OTHER	17.3	0.4	4.8	27.4	49.9
TOTAL	40.9	0.6	22.5	48.8	112.8

Note: (1)Includes local traffic within ports.

Source: U.S Corps of Engineers, Waterborne Commerce of the United States, 1977.

More than 60 million tons of domestic chemical shipments were handled by water with the vast majority moving in shallow draft and coastal barges between domestic locations. Imports and exports included nearly 50 million tons, mostly in the amorphous "other" category, indicating the large number of relatively small volume products being handled. Phosphate was the major export chemical.

Figure N shows chemical movements by water. Major domestic flows are up the Mississippi and Ohio Rivers from the Gulf Coast (with some downbound movement) and to the Northeast, via the ocean, from the Gulf Coast.

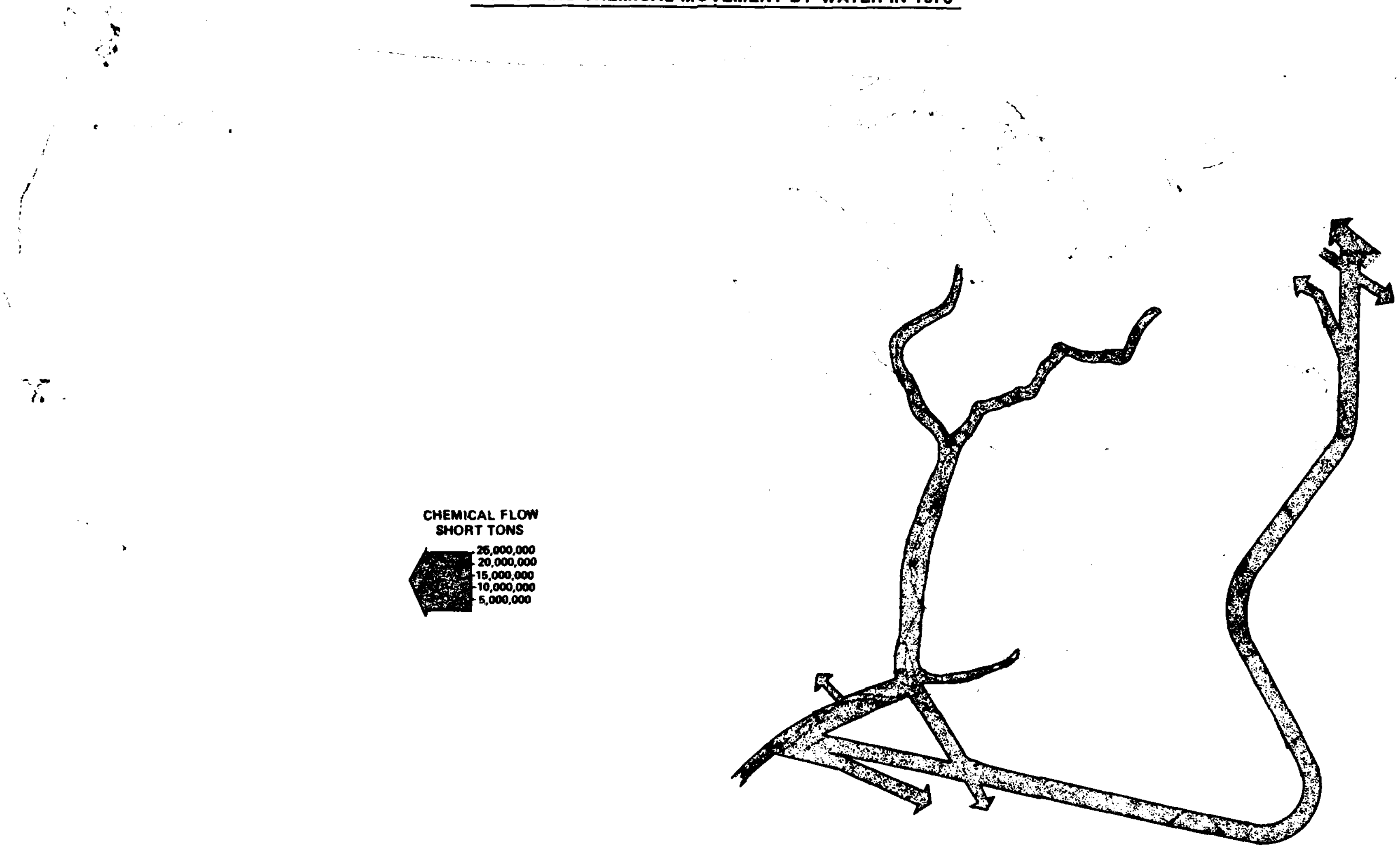
Major logistics issues for industrial chemicals include the following. A large percentage of the products shipped by this industry are officially categorized as hazardous by the U.S. Department of Transportation. Product purity is an important sales factor and chemical companies have established very strict guidelines for avoiding contamination. Both of these require specialized and often dedicated equipment for transportation. Accordingly, the logistics decision process in the chemicals industry is based on concerns for safety as well as cost more so than for the commodities discussed earlier in this section.

Agricultural chemicals account for approximately one-fifth of U.S. chemical sales. Major fertilizers are phosphates (from phosphate rock found commonly in central Florida), nitrogen (produced from natural gas in Louisiana and Texas), and potash (mined in New Mexico or Saskatchewan, Canada).

The fertilizer logistics system begins with a relatively small number of concentrated mining and manufacturing locations for the basic phospate, nitrogen, and potash raw materials. Approximately 5,000 companies, however, are involved in the blending process, mixing these three basic components together to suit the needs of individual farm plots (based on soil conditions and crop mix). The purchasers are the nation's farmers who have

FIGURE N

INDUSTRIAL CHEMICAL MOVEMENT BY WATER IN 1976



Source: Corps of Engineers, Waterways System and Commodity Movement Maps.

traditionally applied fertilizer during a single four-week period each spring. Thus, the fertilizer industry is characterized as having year-round production from a few major sources for consumption during only one month of the year on literally millions of individual farms spread over the nation's land mass.

Traditionally, fertilizers were distributed by rail cars directly to a local dealer who sold it to farmers. More recently, major fertilizer producers have integrated their logistics systems to include bargeload upriver movements from the Gulf Coast of phospate and nitrogen (plus unit trains of potash) to central storage and blending facilities. As a result, water flows of primary fertilizers have increased in recent years. Table 15, includes the waterborne tonnages of major fertilizers and phosphate rock.

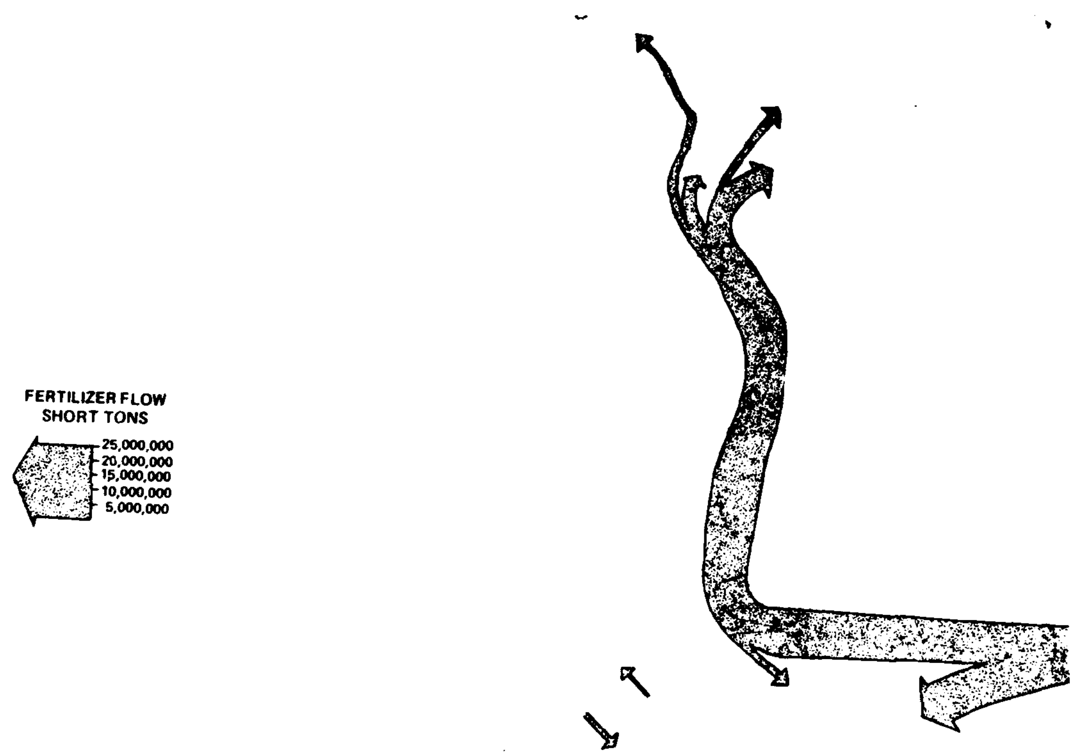
The flows are shown in Figure O. As can be seen, the major movements are by shallow draft barge (up the Mississippi and Illinois Rivers), and by ocean barge (from Florida across the Gulf), and in foreign commerce.

The remaining agricultural chemicals are primarily pesticides and specialty items which move in very small lots (e.g., a five-gallon can or 55-gallon drum) primarily by truck.

Sufficient waterways system capability to accommodate the movement of fertilizer is key to the continued viability of the American agricultural industry and, therefore, important to the nation as a whole.

FIGURE O

FERTILIZER MOVEMENT BY WATER IN 1976



Source: Corps of Engineers, Waterways System and Commodity Movement Maps.

FOREST PRODUCTS

The major forest products produced and consumed in the United States are lumber and plywood for building and paper for printing. Approximately half of the wood products are produced in the far Northwest and shipped by rail to midwestern markets or by water and rail to California. Pulp and paper products are produced primarily in the South. Some portion of these products move by water but the vast majority move by rail or truck to markets in the Midwest, Northeast and South. In addition, the United States imports a substantial amount of forest products from Canada by rail and water.

Waterborne flows of forest products for 1977 are shown in Table 16.

TABLE 16

FOREST PRODUCTS: 1977 WATERBORNE COMMERCE
(MILLIONS OF SHORT TONS)

COMMODITY	DOMESTIC SHALLOW DRAFT(1)	DOMESTIC GREAT LAKES	DOMESTIC COASTS	FOREIGN	TOTAL
LOGS	2.0	0.0	0.0	12.9	14.9
RAFTED LOGS	16.3	0.0	0.0	0.0	16.3
LUMBER AND PLYWOOD	0.4	0.1	1.3	6.4	8.2
PULP	0.8	0.1	0.1	3.1	4.1
OTHER	5.1	0.4	0.7	14.7	20.9
TOTAL	24.6	0.6	2.1	37.1	64.4

Note: (1)Includes local traffic within ports.

Source: U.S Corps of Engineers, Waterborne Commerce of the United States, 1977.

Logs are moved by barge and rafted (i.e., tied together and towed by tug) from the producing areas to major export ports or mills on the West Coast via the Columbia-Snake Waterway and Puget Sound. Forest products are moved in foreign commerce and along the West Coast of the United States for domestic use. Total tonnage of forest products is 64 million, over half of which is in foreign commerce.

Although important in the Northwest, waterborne forest products traffic is a small portion of the transportation needs of that industry and does not appear to have a particularly strategic role in the health of the forest products industry.

OTHER COMMODITIES

Waterborne movements of other commodities are shown in Table 17.

TABLE 17

OTHER COMMODITIES: 1977 WATERBORNE COMMERCE
(MILLIONS OF SHORT TONS)

COMMODITY	DOMESTIC SHALLOW DRAFT(1)	DOMESTIC GREAT LAKES	DOMESTIC COASTS	FOREIGN	TOTAL
SAND, GRAVEL AND CRUSHED ROCK	55.4	0.6	3.0	4.3	63.3
CEMENT	4.5	3.6	1.6	2.9	12.6
METAL SCRAP	1.7	0.1	0.2	6.1	8.1
MARINE SHELLS	12.1	0.0	0.0	0.0	12.1
OTHER	37.9	2.6	4.5	35.6	80.6
TOTAL	111.6	6.9	9.3	48.9	176.7

Note: (1) Includes local traffic within ports.

Source: U.S Corps of Engineers, Waterborne Commerce of the United States, 1977.

Sand, gravel and crushed rock is moved on virtually every waterway and in every port in the United States for use in construction. Total tonnage is more than 63 million per year. Cement adds another 12 million tons per year and scrap metal another 8 million tons. Marine shells, also used for construction, total 12 million tons a year.

"Other" commodities include general cargo (approximately 20 million tons in foreign commerce), nonmetallic minerals such as salt and clay, scrap and waste, and "waterway improvement materials" for the construction of new waterways.

SUMMARY

Table 18 below shows the total from all the prior tables presented in the section.

TABLE 18

ALL COMMODITIES: 1977 WATERBORNE COMMERCE
(MILLIONS OF SHORT TONS)

INDUSTRY	DOMESTIC SHALLOW DRAFT(1)	DOMESTIC GREAT LAKES	DOMESTIC COASTS	FOREIGN	TOTAL	PERCENT OF TOTAL
AGRICULTURE	56.7	1.8	6.5	137.3	202.3	10.6%
PETROLEUM	235.3	5.4	205.3	512.5	958.5	50.0
COAL	130.4	22.2	3.7	55.5	211.8	11.0
METALS	17.6	71.8	0.6	98.7	188.7	9.9
CHEMICALS/FERTILIZER	40.9	0.6	22.5	48.8	112.8	5.9
FOREST PRODUCTS	24.6	0.6	2.1	37.1	64.4	3.4
OTHER COMMODITIES	111.6(2)	6.9	9.3	48.9	176.7	9.2
TOTAL	617.1	109.3	250.0	938.8	1,915.2	100.0%
PERCENT OF TOTAL	32.2%	5.7%	13.1%	49.0%	100.0%	

Notes: (1) Includes local traffic within ports.
(2) Includes Waterway improvement materials from detailed Corps data tapes, not shown in published Waterborne Commerce of the United States, 1977.

Source: U.S. Corps of Engineers, Waterborne Commerce of the United States, 1977.

Total waterborne flows are dominated by petroleum movements accounting for nearly half of all tonnage, followed by coal with 11.0%, agriculture with 10.6%, and the metals industry with 9.9%.

Foreign trade (including Canada) accounted for nearly half of all waterborne tonnage and is also dominated by petroleum movements. Shallow draft waterways added about a third, domestic coastal traffic 13.1% and Great Lakes/St. Lawrence Seaway 5.7%.

Several key conclusions emerged from an understanding of the logistics process of the industries discussed in this section.

Transportation decisions on both routing and mode choice are integrated with a wide variety of raw materials sourcing and capital investment decisions. They are not viewed in isolation. **As a result, waterborne logistics decisions tend to be part of strategic long-term commitments to fixed facilities and patterns of distribution.** Therefore, the principal concern of the companies which use the waterways is the total logistics cost over the life of the investment. This includes the relative cost and quality of raw materials from various sources, the cost of feeder and distributor transportation, the basic linehaul cost by each mode, handling into and out of vessels, inventory costs for product in transit, and expected long-term inflation rates for each component. **Therefore, long-term reliability of the logistics system, since it ties into long-term commitments to supply sources, customers, and capital investments, is of critical importance.**

Once a movement is committed to a water transportation leg as a part of its total logistics process, that movement is not likely to be switched to another mode of transportation. The only circumstances under which a switch is likely to occur are:

- A major shift in one of the logistics components of the industry (e.g., the shift from eastern to western coal).

- The water transportation is unavailable due to disruption of the navigation system (e.g., a lock closure).

- The long-term reliability of the water transportation system is unsure (whether a key lock will be replaced in time to avoid long delays).

- A major shift in the relative economics of the mode of transportation (e.g., a major increase in the cost of water versus rail).

Note that three of the four potential disruptions of the logistics system are directly influenced by the long-range management strategy for the navigation system.

Finally, it should be noted that a thread has run through all of the discussions in this Section: the importance of the water-based logistics system to the viability of industries

which are of major importance to the national economy and defense. Thus, a healthy and productive navigation system is important not only to the individual industries, states, and cities which border the waterways, but also to the economic health of the entire nation as well.

IV - CONCLUSIONS FROM TECHNICAL RESEARCH

During the course of the National Waterways Study effort, eleven detailed technical reports were prepared. This section presents major findings and conclusions from those reports which are relevant to the overall findings and conclusions of the study. This section will cover the review of data bases used during the study, overview of the transportation industry, national defense and emergency issues affecting navigation, navigation relationships to other water uses, waterways science and technology, and environmental aspects of navigation.

REVIEW OF DATA BASES

Three of the principal data bases used as part of the National Waterways Study were concerned with the operation of locks, federal expenditures in support of navigation and historic commodity flow information. **Each data base requires improvement to fully support future navigation analysis.**

1. Lock Operations. The source of much of the data about the operation of locks on the nation's waterways comes from the Performance Monitoring System (PMS), installed by the Corps of Engineers beginning in 1975. Although this system provides better data than were available previously, there are still several improvements that need to be made. In addition, PMS needs to be expanded to full coverage of all locks operated and maintained by the Corps of Engineers. Its use should be enforced so that accurate and complete data are available for future analysis of the nation's waterways as a system. Concurrent with such renewed emphasis on PMS, it would appear appropriate to carefully review the data being collected (in light of the analysis conducted during this study) to ensure that all necessary data for future analysis is adequately being provided. For instance, capturing data about noncargo carrying commercial vessels, such as offshore supply boats and fishing craft, is critical at some locks.

2. Federal Expenditures. During the National Waterways Study, the Corps of Engineers attempted (for the first time) to prepare a comprehensive data base of the federal expenditures for various purposes in support of the navigation system. Although these data are better than the absence of data which prevailed previously, they are still inadequate for comprehensive planning and management of the navigation system from the national perspective. Several improvements are necessary as indicated on the following page.

● Consistency of definitions used among District Corps Offices in collecting the data.

● Completeness of coverage of all data elements by each District.

● Inclusion of all federal costs for operation of the navigation system including those incurred by the Mississippi River Tributaries Project (included elsewhere in the Corps budget) and Coast Guard navigation support.

● Assignment of costs incurred for multipurpose water projects to navigation in a consistent manner that reasonably reflects the true economic cost of the navigation system.

● Classification of expenditures assignable to deep draft ocean shipping versus shallow draft inland navigation support.

3. Commodity Flows. The main source of commodity flow information by water is the Waterborne Commerce Statistics (WCS) produced by the Waterborne Commerce Statistics Center in New Orleans (a part of the Corps of Engineers). Although these data are far better than similar data for all other modes of domestic transportation, there is still room for improvement. Two major issues can be identified. During the course of ongoing navigation studies by the Ohio River Division of the Corps, discrepancies were discovered between the WCS data base and other sources. The Division found that the WCS data have understated coal movements on the Ohio and Monongahela Rivers by as much as 10%. How widespread the underreporting might be is unknown at this time. The second issue relates to the inadequacy of the classification system for chemicals -- with the number of products having exploded in recent years. As a result, much of the chemical traffic is classified as "other." Better detailing of the chemical classification system would greatly facilitate future analyses.

OVERVIEW OF TRANSPORTATION INDUSTRY

This discussion will cover a comparison of transport modes, a description of the marine industry and ports and terminals.

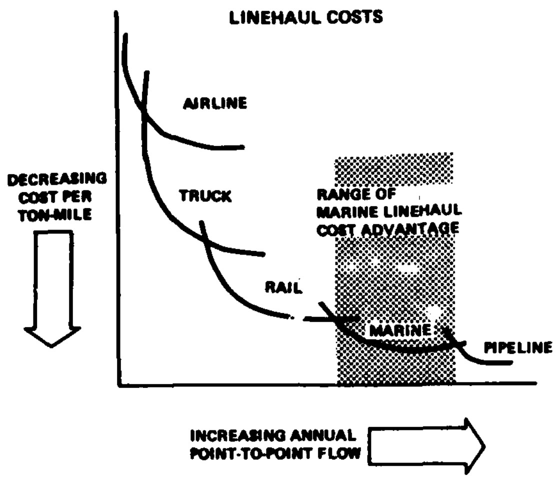
(a) Comparison of Modes

Each mode of transportation has an inherent role to play in

the nation's domestic transportation system based on its underlying cost structure and its cargo carrying capacity. This is shown schematically in Figure P.

FIGURE P

TRANSPORTATION COSTS BY MODE



Source: A. T. Kearney, Inc. Domestic Waterborne Shipping Market Analysis

This figure shows that within each mode, the cost per ton-mile decreases as the annual point-to-point volume increases, allowing each mode to assume its maximum economies. For instance, a single rail car shipment of product requires multiple switching and handling between origin and destination, while a unit train of coal or grain can be handled intact at a much lower cost per ton. Similarly, a single barge load of cargo on a small or shallow river incurs a much higher cost per ton-mile than a 40-barge tow (of 60,000 tons) on the Lower Mississippi.

The figure also shows the inherent advantage of each mode relative to others based on an increasing point-to-point flow. Therefore, the inland marine mode has an advantage over both rail and pipeline for a particular spectrum of shipments -- particularly those that are shipped in lots from 1,500 to 60,000 tons between points where a logical routing includes a major waterway. The same argument applies for Great Lakes bulk carriers and ocean tankers.

Note that domestic marine transportation does not compete with either truck or airline modes. In fact, the truck mode is often complementary by hauling grain or coal a short distance to the river or distributing chemicals, petroleum, or fertilizer to customers.

In the past few years, the airline, truck, and rail industries have been substantially deregulated. The domestic marine industry has been, by and large, unregulated from its inception and only pipelines remain as a regulated transporation industry. This shift in the regulatory framework will have major implications for each of the industries involved. Of particular interest is the deregulation of the domestic rail industry.

The major impact of rail deregulation for the waterways is that the rail carriers will become far more profit conscious -- and, therefore, more effective competitors -- than in the past. The traditional rail rate structure under ICC regulation involves massive cross subsidization of one commodity by another, one origin/destination pair by another, and one shipment size by another. In the relatively deregulated ratemaking environment of the 1980s, rail rates are rapidly converging on the underlying cost structure of providing the service. Thus, depressed rates will rise rapidly to cover rail costs and high rates will be driven downward by powerful shippers. **Thus, rail/water competition will be carried out in a free market environment for the first time since the passage of the Interstate Commerce Act in 1887.**

By and large, the marine industry need not fear this new form of competition. Generally, the marine mode has a substantial cost advantage (as shown in Figure P) for movements of major tonnages on major waterways. Only relatively small volume shipments on relatively obscure waterways serving limited markets are likely to be adversely affected.

(b) The U.S. Marine Industry

One focus of the review of the marine industry was to develop a profile of the industry in terms of size, investment, profitability and productivity. Table 19 presents a profile of U.S. marine carriers.

The table shows that there were approximately 500 significant water carriers in 1977 employing nearly 25,000 people. They operated nearly 2,000 self-propelled vessels, 30,000 barges, and more than 4,000 tugs and towboats. **The replacement value**

of the U.S. water carrier fleet is approximately $91 billion. Shallow draft equipment represents approximately $10 billion of investment and the Great Lakes fleet represents nearly $14 billion. The vast majority of the U.S. flag investment is in oceangoing tonnage with more than $67 billion in replacement value.

TABLE 19

PROFILE OF U.S. MARINE CARRIERS, 1977

ITEM	SHALLOW DRAFT	GREAT LAKES	U.S. FLAG OCEANGOING	TOTAL
NUMBER OF U.S. FIRMS(1)	299	36	141	476
EMPLOYMENT BY CARRIERS	12,385	1,123	9,975	23,483
AMOUNT OF U.S. EQUIPMENT(1)				
SELF-PROPELLED	0	313	1,535	1,848
BARGES	28,514(2)	256	0	28,770
TUGS AND TOWBOATS	2,614	148	1,617	4,379
TOTAL	31,128	717	3,152	34,997
REPLACEMENT VALUE OF U.S. EQUIPMENT ($ MILLION)				
SELF-PROPELLED(3)	$ 0	$13,972	$65,667	$79,639
BARGES	7,100(3)	56	0	7,156
TUGS AND TOWBOATS	2,677	115	1,520	4,312
TOTAL	$9,777	$14,143	$67,187	$91,107

Notes: (1)Excludes ferries.
(2)Includes barges operating on coasts.
(3)Based on Maritime Administration data.

Sources: Army Corps of Engineers, Unpublished Data; Maritime Administration; Bureau of Census, County Business Patterns.

The shallow draft inland and Great Lakes carriers have been aggressively innovating to improve operating productivity. Vessel and towing technology has been improved and sizes and speeds have been increased essentially to the limits of the physical navigation system currently in place. Lake bulkers have been automated to decrease port turnaround time and designed to maximize the tonnage carried on each voyage, restricted only by the size of the constraining locks and the operating season of the waterway. As a result, productivity has improved substantially in the past several decades. Crew productivity on a major barge tow, for instance, has improved forty-fold over the past 40 years. **Fundamentally, the marine transportation operators, in a free enterprise environment, have maximized their return from the available federally-provided navigation right-of-way.**

As a result, domestic water carriers have traditionally been profitable and financially healthy enterprises. For instance, in a study conducted in 1972/1973, inland waterways carriers on average reported a return on equity of 10.6% after taxes. This return was quite favorable in relation to the rest of the transportation industry.

Now, however, little further significant productivity improvement can be expected without significant modifications to the navigation system itself. **In fact, carriers indicate that there has been a deterioration of the navigation system in recent years.** Factors responsible for this deterioration include congestion at locks and less reliable channels due to reduced dredging by the Corps (often in response to environmental restraints). In addition, fuel cost increases, and recent severe winters have contributed to reduced productivity. As a result, average return on equity reported by shallow draft carriers during a similar survey conducted as a part of this study revealed a return on equity of only about 7.6%.

However, none of the research or interviews conducted during the study suggest that there will be a significant likely shift in traffic away from the marine mode in the future. The shipping patterns that involve water transportation tend to be extremely stable. Thus, barring some shift in sourcing (such as western versus eastern coal), there is likely to be little shift in traffic patterns for major movements currently being handled by the marine mode, if current navigation system capability is maintained. Navigation system capability is discussed in depth later in this report.

(c) Ports and Terminals

Federal involvement in ports and terminals has generally been limited to the construction and maintenance of access channels, turning basins, and safety-related structures. **There is little evidence of capacity constrained ports limiting the long-run volume of domestic and foreign commerce.** Terminal and cargo handling facilities have, from time to time, been overburdened. However, the private sector has invested in additional capacity and is expected to continue to do so. In fact, terminal capacity constraints have generally led to overbuilding which is the present case for general cargo container facilities and is likely to be the case for export coal-loading terminals by the mid-1980s.

The major concerns for the future of ports relate to reduced channel reliability from limited dredging (due to environmental restrictions), vessel safety as traffic and congestion increase, and sufficient land for terminal development. An additional issue is a desire for deeper access channels to accommodate larger (and therefore more efficient) bulk carriers, primarily for coal. This will be addressed as a part of the strategy development later in this report.

At shallow draft river ports, the key unique issue is the opportunity to improve overall system productivity by improving cargo handling facilities. As shippers take the lead in developing integrated logistics systems involving a water link, the general level of cargo handling investment will increase and productivity improvement should follow.

NATIONAL DEFENSE AND EMERGENCY ISSUES

One of the major uses of the navigation system for defense is the staging and shipping of material and people for overseas deployment via the major ocean ports. Deep draft harbors also provide refuge and support facilities for naval vessels. **Generally, these require no special navigation capability beyond the reasonable maintenance of the existing major ports.** Most cargoes and people will be moved to and from those ports by rail and road.

The other major purpose of the navigation system for defense is the reserve capacity it provides for the steel industry for which production must be increased sharply during a full scale military conflict. There are several vital navigation links to move raw materials to integrated mills (the Great Lakes) and to move steel products to plants for fabrication (Illinois, Lower Upper Mississippi, and Ohio Rivers). The limitations of the present navigation system under a defense emergency are discussed in Section VII.

Emergencies which might impact normal operations of the waterways system include hurricanes, extreme high floods, lock failures, and extremely severe winters. Occasionally, one of these events causes a major disruption on one of the waterways for a short period of time. **However, the normal annual disruption from such emergencies is extremely low and most waterways remain open for navigation more than 99% of the time that they are scheduled to be open.**

Even extreme disasters have been handled well. It has been estimated that the Mount St. Helen's eruption dumped 40 to 50 million cubic yards of sediment into the Columbia River, closing it to navigation. However, rapid action by the Corps and other federal agencies successfully reopened a navigation channel in less than two weeks.

ANALYSIS OF NAVIGATION RELATIONSHIPS TO OTHER WATER USES

The National Waterways Study was charged to examine non-navigation water resource demands which could potentially conflict with (or complement) navigational use of the waterways. Some of the demands which were evaluated included irrigation, hydropower generation, recreation, commercial fishing and offshore oil exploration.

Thorough analysis during the National Waterways Study found **no forseeable shortage of water supply for navigation purposes during the remainder of this century.** The only modest possibilities for water shortages for a significant period of time (under extreme drought conditions) were on the Missouri River due to diversions of reservoir water for irrigation purposes.

Hydropower generation is generally complementary to navigation use since it does not divert water away from the mainstream. The only possible conflicts with navigation are on the Alabama River and at the Barkley Dam on the Cumberland River since they are used primarily for peaking power generation where water releases may not coincide with the needs of navigation.

The primary interaction between recreation and navigation is the use of pleasure boats which conflict in harbors and at locks. **In harbors, the prime issue tends to be safety-related, where recreational and commercial craft are mixed at the same time and place.** However, there are also many small harbors on the coasts and on the lakes which are used exclusively by recreation craft -- yet maintenance costs are charged to commercial navigation accounts in the Corps' accounting system. **At locks, recreation craft may be locked through along with commercial craft. Therefore, there is relatively little real conflict.** A special analysis conducted during this study revealed that for

locks on the Upper Mississippi and Illinois waterways, the additional demand of recreational craft did not change this study's findings regarding constraining locks. While recreational craft do not affect commercial traffic significantly, the converse is not always true. Recreation craft may be delayed by commercial navigation, particularly at locks.

Commercial fishing vessels (of five net tons or more) totaled nearly 17,000 in 1976 and there were an additional 86,000 commercial fishing boats of smaller size. The industry employed 176,000 people -- an increase over 1975. Principal fishing ports in the domestic United States include San Pedro, California; Cameron, Louisiana; Dulac-Chauvin, Louisiana; and Pascagoula, Mississippi. In total, the United States accounted for 4% of world landings (catches) of fish -- making the United States the world's sixth largest producer. Total U.S. landings of 2.7 million tons were valued $1.3 billion.

Maintenance of many harbors used exclusively for fishing is also charged to the Corps' commercial navigation account. Certainly, the nation's fishing industry is an important one. However, national support of that industry might be considered separately from that of cargo transportation use of the navigation system because of the different objectives and needs of fishing compared to cargo transportation.

The United States had 604 active offshore oil platforms as of 1978. Seventy-two of them were installed during 1977. Total offshore oil production has increased from less than a million barrels in 1953 to nearly 317 million barrels per year in 1976. Serving these offshore facilities are 632 registered **supply vessels and tugs,** mostly concentrated along the U.S. Gulf Coast. These vessels **conflict with other forms of commercial navigation only in their use of common facilities,** such as approach channels and the Inner Harbor Lock at New Orleans.

WATERWAYS SCIENCE AND TECHNOLOGY

The analysis of this subject during the National Waterways Study revealed no likely breakthroughs in technology which are likely to render obsolete existing investment or dramatically increase the productivity of the nation's waterways system. However, 15% to 20% increases in throughput at existing locks can be obtained from more effective scheduling and operation of the existing facilities. This would come from improved utilization

of the existing chambers by packing a full complement of barges or vessels during each chambering cycle. These productivity increases could delay by several years the need for expanding physical lock structures in response to increasing traffic.

River training (the use of shoreside structures to control river currents) has greatly reduced dredging in the Missouri and is expected to reduce dredging on the Lower Mississippi when the 12-foot deepening project is completed. **Greater use of river training could potentially reduce overall dredging requirements for open rivers.**

There is no cohesive research and development program aimed at improving the overall management of the nation's waterways system. The research and development which is performed is generally devoted to solving specific engineering or design problems leading to individual authorized projects. As a result, the proverbial "wheel" is often reinvented. **If waterways research and development were managed more comprehensively, greater overall value would likely be obtained from research funds.**

ENVIRONMENTAL ASPECTS OF WATERWAYS NAVIGATION

There are four major actions associated with the development, maintenance, and operation of the waterways which potentially have environmental impacts of some significance if mitigating actions are not taken. These are:

- Dam construction that creates pools which inundate otherwise dry land and change seasonal flow patterns.

- Maintenance dredging in polluted areas which dredges up pollutants from the waterway bottom.

- Unwise or unplanned disposal of dredged material in an environmentally harmful manner.

- Spills or other hazards resulting from commercial nagivation.

Construction of new waterways will tend to receive close environmental scrutiny since they raise water pool levels and change seasonal flow patterns. **However, replacement of existing dams or replacement or expansion of other facilities that do not raise pool levels have few direct environmental impacts.** To

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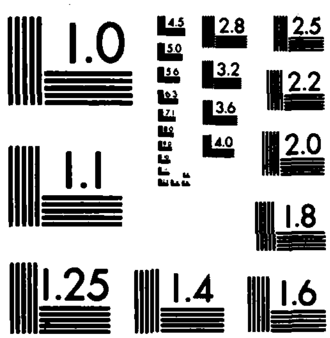


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

the extent that increased traffic accommodated by increased lock capacity has detrimental effects, then these effects can be associated with lock capacity expansion actions.

Generally, dredging itself creates only modest and very temporary environmental impact, mostly in the form of increased turbidity for short periods of time. Dredging itself is a real issue primarily where the bottom has become polluted with toxic chemicals and where the resuspension of these could create a potential health hazard. This is likely to be an issue only with selected port deepening actions which have been proposed.

Disposal of nonpolluted dredged material in open water generally has modest and short-lived environmental impacts. However, in many parts of the navigation system, open water disposal is no longer allowed. As a result, dredged material must be deposited on dry land in diked containment areas at greater cost. Availability of land for dredged material disposal is a major limiting factor on dredging in some parts of the country.

The amendments to the Clean Water Act of 1977, for the first time, required the Corps of Engineers to obtain State-issued permits prior to dredging the national waterways. The state of Wisconsin, for example, has required upland disposal of dredged material and/or delayed the approval of Corps plans for maintenance dredging -- dramatically increasing the cost of dredging and posing navigation hazards to the movement of interstate commerce. As a result, the state has effectively curtailed the Corps of Engineers from exercising its federal mandate to maintain the nation's waterways system for the movement of interstate commerce. This conflict was created by the Congress and the Congress will need to resolve it either by eliminating the current conflict or appropriating sufficient funds for the additional dredged disposal costs.

Waterways spills of toxic or hazardous substances could have a potentially serious environmental and public safety impact. However, the safety record of the barge and towing industry is far superior to that of other alternative modes of transportation for moving such materials (with the exception of pipelines) based on a study conducted by the Maritime Administration in 1975.

V - FORECAST OF POTENTIAL WATER TRANSPORTATION USE

This section will briefly discuss assumptions which underlie the forecasting process and summarize the six sets of forecasts produced during this study for each of the major waterways industries discussed in Section III.

ASSUMPTIONS ABOUT THE FUTURE

No one knows for sure what the future holds. Thus, a national strategic planning study based on a single forecast of the future would inevitably be compromised by the passage of time and the occurrence of unexpected events. Therefore, six alternative sets of forecasts were prepared and all succeeding analyses were performed six times, once for each "scenario." The six scenarios are named and described as follows.

1. Baseline. This scenario calls for continuation of presently well-established trends and discernable conditions. The baseline is not a "most likely" scenario but is a benchmark against which variations among scenarios can be judged. Past trends are unlikely to continue without some change.

2. High transportation use. This scenario assumes that basic underlying economic conditions and government policies are those that tend to stimulate greater demand for transportation in the major industries that use water transportation. Specifically, it is assumed that there is a decline in construction of new nuclear power plants, increasing the consumption of coal. It is also assumed that coal exports are increased and that phosphate exports continue at a high rate.

3. Low transportation use. This scenario reflects a combination of economic and government policy events that tend to depress the demand in industries which are major users of water transportation. Specifically, it is assumed that the rate of growth of the government increases at a rate higher than the overall economy, crude oil imports are substantially below the level in the baseline scenario, few synfuel plants are actually constructed, there is a relaxation of environmental emission standards affecting the coal sourcing decisions of utilities, agricultural crop yields are stable rather than growing, and steel imports gain a greater share of the U.S. domestic market.

4. <u>Bad energy</u>. This scenario hypothesizes an energy crisis in the mid-1980s with resulting impact on the economy of the nation. Specifically, oil prices rise faster than in the baseline scenario, foreign crude oil supplies are tighter, imports of foreign crude drop precipitously, coal exports are greater than in the baseline, additional synfuel plants are constructed along the waterways, and seven coal slurry pipelines are built.

5. <u>High coal exports</u>. This scenario is a variation of the high use forecast. It assumes that the U.S. will dramatically increase its coal exports over the next 20 years to nearly 300 million tons in 2003. This forecast is based in part upon data provided by the National Coal Association.

6. <u>Defense</u>. This scenario is also a variation of the high use forecast and assumes that the U.S. is engaged in a five-year conventional war from 1986 to 1990. At the height of the conflict in 1990, the U.S. is engaged on two fronts, both of which are overseas. This forecast is based on data provided by the Federal Emergency Management Agency.

A more detailed review of the specific assumptions that vary from one scenario to another are presented in Exhibit III near the end of this report.

The basic forecasting methodology involved the following steps:

- The national economy was modeled using the Data Resources Inc. (DRI) macroeconomic models. Different model assumptions are embodied in each set of forecasts. Assumptions about the likely trends in U.S. population growth were based on the latest Bureau of Census information and were the same for all scenarios.

- A detailed analysis was performed of each of the major industries which significantly affect water transportation tonnage using both field interviews and ongoing DRI modeling capabilities.

- Industry forecasts were regionalized to project production and consumption in specific geographic areas. These projections were based in part upon analysis of historical industry data.

- Each industry's logistics decision process was replicated to identify the likely transportation decisions which would be made. Waterborne projections were based in part upon

correlations between broad economic and industry factors and historical waterborne flows for 1969 to 1977 as well as a full consideration of likely shifts in logistics systems by industry due to new plant locations or new product introductions.

- The industry analysis, production and consumption regions, and logistics decision process for each industry were adjusted to reflect the effects of the individual scenario assumptions shown in Exhibit III.

The resulting six sets of projections of potential waterborne commodity flows were developed from 1977 to 2003 in five-year increments for 14 commodity groups and 22 reporting regions as shown in Exhibits I and II. These projections were "unconstrained" by any shortfall in the waterway capability to handle the traffic. Therefore, the six sets of projections represent the most likely cargo levels available for water transportation under each of the six sets of assumptions. Whether the present navigation system can accommodate these projected flows is discussed in Section VII.

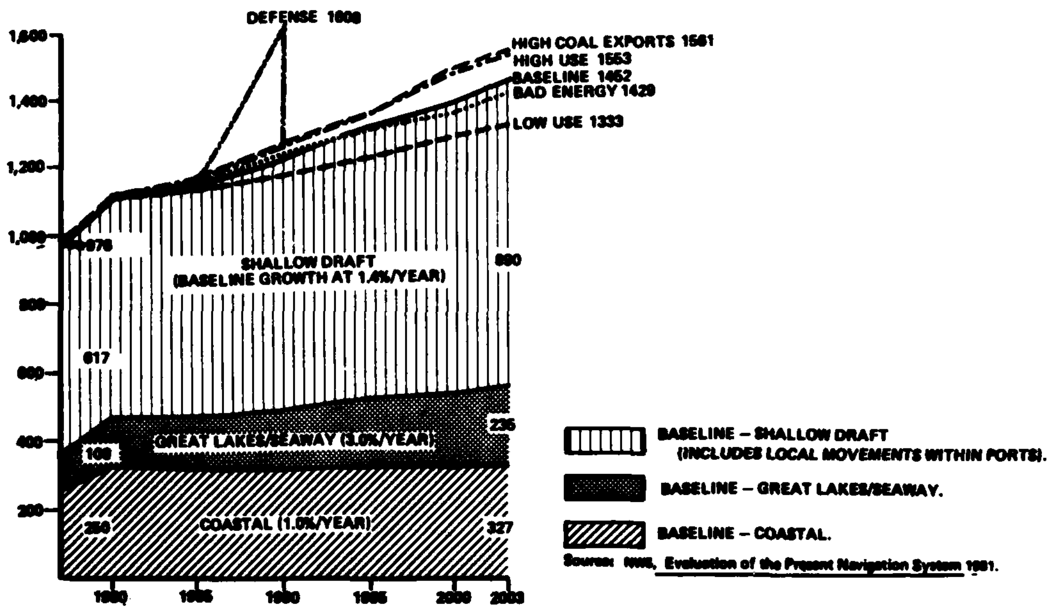
In addition to the six scenarios, miscellaneous adjustments to the high use scenario were tested to determine if they affected study conclusions. These adjustments include changes to the traffic levels as reported by WCS for 1977 in the Ohio River Region and at the Inner Harbor Navigation Canal Lock. In addition, these adjustments involve upward revisions of the DRI forecasts on the Arkansas for all traffic and on the Columbia-Snake waterways for sand and gravel. These adjustments were made at the suggestion of the Corps of Engineers and the general public resulting from a public review of the basic forecasts.

FORECASTS OF TOTAL TONNAGE

Figure Q on the following page shows the alternative forecasts of potential domestic waterborne tonnage from 1977 through 2003, unconstrained by the waterways capability to handle the traffic. The data are based on tons loaded which (except for minor losses) equal the tons unloaded.

FIGURE Q

UNCONSTRAINED FORECAST OF DOMESTIC WATERBORNE TONNAGE 1977-2003
(MILLIONS OF TONS)



Source: NWS, Evaluation of the Present Navigation System 1981.

In 1977, 250 million tons of cargo were handled in coastal domestic trade and to and from Hawaii, Alaska and Puerto Rico. An additional 109 million tons were handled in the Great Lakes and St. Lawrence Seaway from ports in the United States. A total of 617 million tons were handled by shallow draft inland waterways in 1977, bringing the total 1977 tonnage to 976 million tons.

By the year 2003, under the baseline scenario, the potential traffic is projected to be 327 million tons in the domestic ocean trade, 235 million tons on the Great Lakes and 890 million tons on the shallow draft inland waterways. This brings the total potential tonnage in 2003 under the baseline scenario to 1,452 million tons, an increase of 49% from 1977. Under the low use and bad energy scenarios, the totals are projected to be only 1,333 million tons and 1,429 million, respectively. The highest projected potential tonnages in 2003 are estimated to be 1,533 and 1,561 million under the high use and high coal export scenarios, respectively.

Average annual growth rates for domestic tonnage under the baseline scenario are shown in Figure Q. Overall, the percentage increases 1977-2003 are 37% for low use, 46% for bad energy, 49% for baseline, 59% for high use and 60% for high coal export.

The hypothetical war in the defense scenario causes a major build up of tonnage to more than 1,600 million tons at the height of the conflict (in 1990) compared to a baseline projection of 1,229 million tons. The differences are primarily in petroleum and steel production, which will be discussed later in this section.

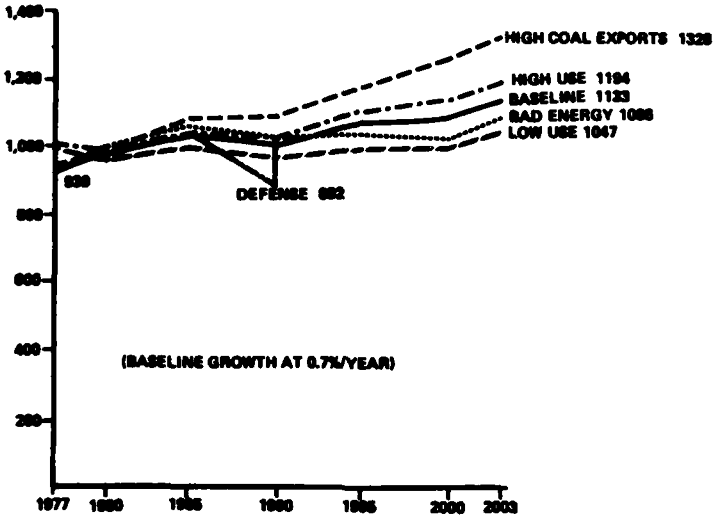
Because the waterways carry primarily bulk commodities which move in very stable patterns and which are backed by large fixed capital investment in plants and facilities, the overall tonnages are affected only modestly by differences in assumptions about the economy and the health of individual industries. Thus, the differences in overall tonnage are modest under five of the six alternative scenarios of the future. The defense scenario is the exception.

Figure R, on the next page, displays the unconstrained forecasts of potential import/export tonnage. It reflects the sum of shipments and receipts.

FIGURE R

UNCONSTRAINED FORECAST OF FOREIGN WATERBORNE TONNAGE 1977-2003

(MILLIONS OF TONS)



Source: NWS, Evaluation of the Present Navigation System 1981

Total foreign commerce moves from a base of 939 million tons in 1977 to 1,133 million tons under the baseline, an increase of nearly 21%. Low use is 1,047 million tons in 2003, while bad energy is 1,086 million tons and high use is 1,194 million tons. The high coal export scenario projects total foreign commerce to be 1,328 million tons in 2003. During the hypothetical conflict assumed in the defense scenario, imports and exports fall to 892 million tons at the peak year of the conflict versus a baseline of 1,008 million tons.

Although the growth in import/export tonnage appears both modest and steady, it is, in fact, made up of significant changes of tonnage in several industries, as will be discussed later in this section.

The overall forecasts of potential waterborne tonnage are shown for the 22 NWS regions in Exhibit IV at the end of this report. Exhibit IV shows the tonnage passing through each region in 1977 and projected to pass through each region in 2003 for each scenario, on the assumption that the navigation system has sufficient capacity to handle all the tonnage available to it.

For perspective, the baseline water transportation forecasts were compared to rail and pipeline forecasts with essentially the same underlying assumptions. The results are shown in Table 20.

TABLE 20

NATIONAL FORECASTS BY MODE

MODE	MILLIONS OF TONS 1977	2003	CHANGE	PERCENT CHANGE
RAIL	1,391	2,619	1,228	88%
WATER - DOMESTIC(1)	976	1,452	476	49
WATER - FOREIGN(1)	939	1,133	194	21
PIPELINE	1,172	1,401	229	19
TOTAL	4,478	6,601	2,123	47%

Note: (1) Baseline forecast for 2003.

Source: Data Resources, Inc.

Note that although domestic water transportation increases approximately 49% over the quarter century spanned by the data, rail transportation increases by 88%. The reason is the heavy projected increase in coal transportation by rail to support the nation's domestic and export needs. Foreign waterborne commerce is projected to increase only 21% over the quarter century due to the reduction in crude oil imports from foreign sources. As a result of the nation's lower dependence on petroleum as a prime source of energy, pipeline increases are also modest under the baseline scenario assumptions.

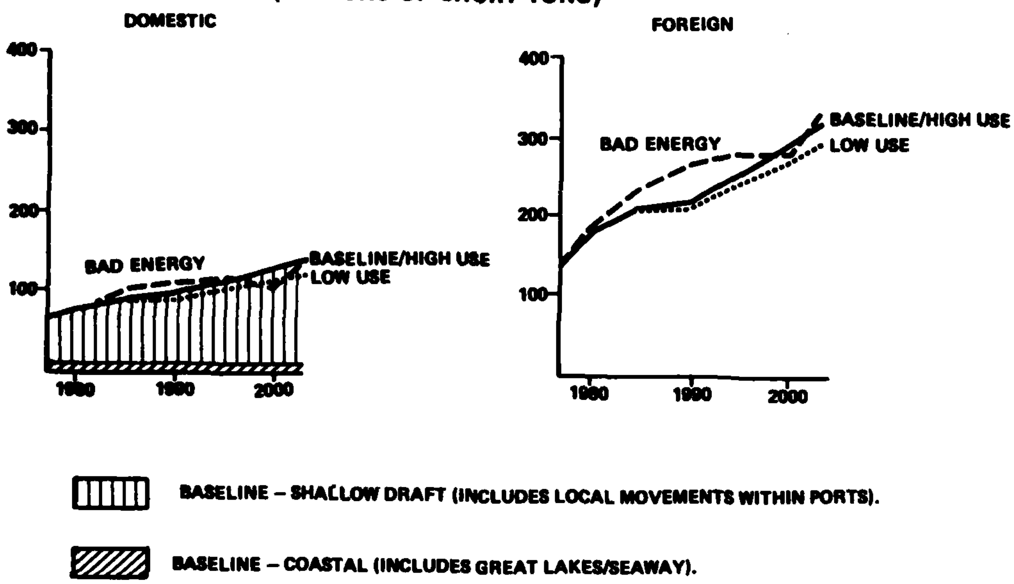
AGRICULTURE

Figure S, on the next page, shows the unconstrained projections of potential waterborne tonnage for domestic and foreign transport of agricultural products between 1977 and 2003 for each applicable scenario.

FIGURE S

UNCONSTRAINED FORECAST OF WATERBORNE AGRICULTURE TONNAGE 1977-2003

(MILLIONS OF SHORT TONS)



Source: NWS, Evaluation of the Present Navigation System 1981.

Domestic agriculture tonnage grows at a rate of 2.9% per year compounded from 65 million tons in 1977 to 136 million tons in 2003 under the baseline scenario. This is driven primarily by exports to world markets which grow from 119 million tons in 1977 to 286 million tons in 2003 under the baseline scenario. Growth in foreign trade under the bad energy scenario is somewhat faster (perhaps due to the need for additional exports to pay for crude oil imports).

As a result, substantial increases in grain tonnage are seen on the Upper Missisippi River (up 152% over the quarter century), Lower Upper Mississippi between the mouth of the Illinois Waterway and Cairo, Illinois (up 118%), and on the Lower Mississippi River to New Orleans. The Illinois Waterway's increase is 123%. Clearly the growth of export grain trade down the Mississippi River from the upper Midwest producing area is substantial.

Other significant increases in grain traffic are found in exports from Houston and Galveston to foreign sources after an inbound movement to the port by rail. Also served by rail is a significant increase in grain export from the middle Atlantic ports of Hampton Roads, Baltimore and Philadelphia. The Great Lakes/St. Lawrence Seaway, Columbia-Snake Waterway, and California Coast also see significant increases in grain exports.

The agricultural forecasts are shown by region in Exhibit V at the end of the report.

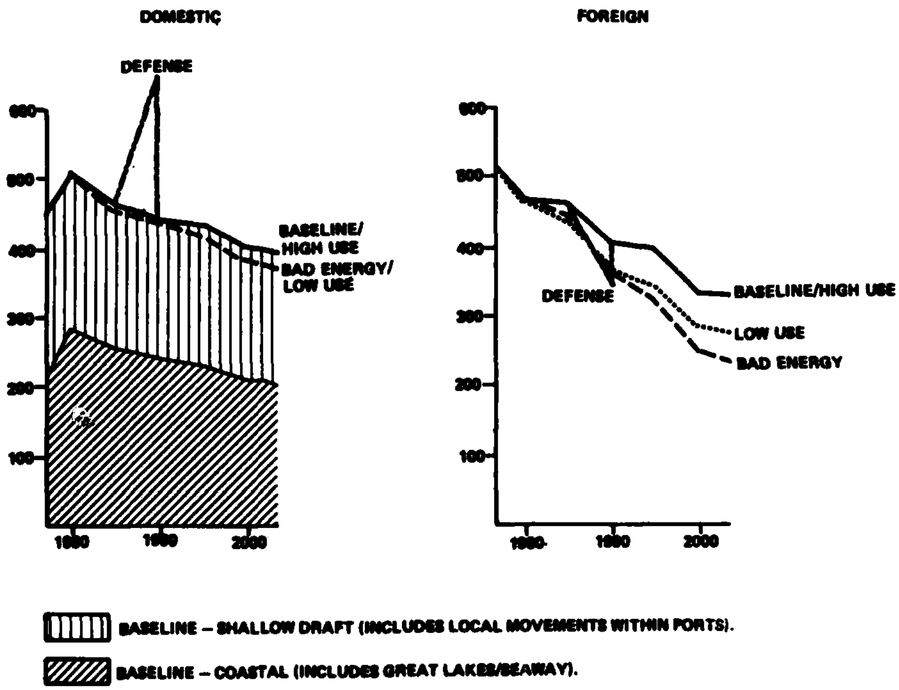
PETROLEUM

Figure T displays the forecast of waterways tonnage of petroleum.

FIGURE T

UNCONSTRAINED FORECAST OF WATERBORNE PETROLEUM TONNAGE 1977-2003

(MILLIONS OF SHORT TONS)



Source: NWS, Evaluation of the Present Navigation System 1981.

Domestic transportation of petroleum and petroleum products by water declines modestly over most of the 25-year forecast period. The reason is that absolute consumption of petroleum begins to decline as the high price encourages conservation. Much of the decline is a result of the conversion of oil-fired power generating plants to coal. Since pipelines have a far lower cost structure than water carriers, the pipeline tonnage will remain at high levels (because of the desire by shippers to make full use of their high fixed investments). Thus, the decline in tonnage will be absorbed almost entirely by the marine mode.

This decline affects both the coastal tanker movements between the Gulf and the East Coasts and the shallow draft distribution of petroleum products. Partially offsetting the decline in Gulf/East Coast trade is a dramatic increase in Alaska to West Coast movement of crude oil from the Alaskan pipeline at Valdez.

The hypothesized five-year conventional war in the defense scenario causes an increase of about 200 million tons per year of domestic waterborne petroleum movements in support of the overseas mobilization.

Foreign trade in crude oil and products decline precipitously under all scenarios during the forecast period. Exports fall from 14 million tons in 1977 to zero. Estimates of the decline in trade from the 512 million tons in 1977 range to a low of 231 million tons under the bad energy scenario and a high of 328 million tons under the baseline and high use scenarios. The defense scenario causes a distortion of about 72 million tons in normal trading patterns at the height of the hypothesized conflict.

Exhibit VI shows the petroleum tonnages broken down by NWS region. Major tonnage declines are recorded on the coastal regions of the Lower Misssippi River between Baton Rouge and the Gulf of Mexico, the Gulf Intracoastal Waterway west of New Orleans, the Middle Atlantic Coast and the California Coast.

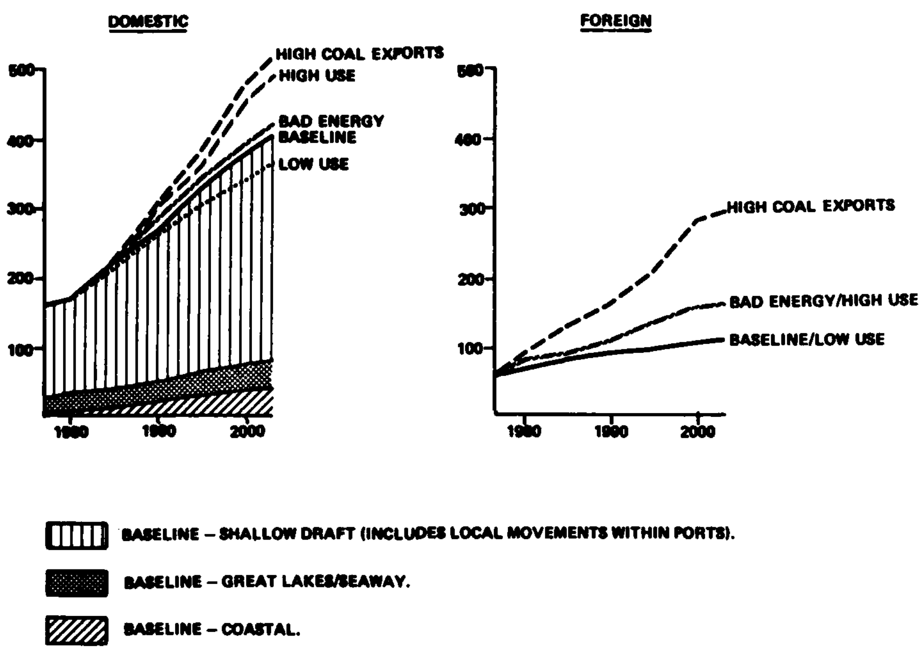
Thus, a major conclusion to be drawn from the discussion above is that the substantial decline in the dependence of the U.S. on foreign oil will result in a significant decline in the amount of water transportation capacity needed by the petroleum industry.

COAL

Figure U shows the forecast for coal tonnage divided between domestic and foreign trade.

FIGURE U

UNCONSTRAINED FORECAST OF WATERBORNE COAL TONNAGE 1977-2003 (MILLIONS OF SHORT TONS)



Source: NWS, Evaluation of the Present Navigation System 1981.

The dramatic increase in domestic water transportation of coal is apparent in all scenarios. Growth from the 156 million tons in 1977 ranges to a low of 365 million tons under low use (134%) and a high of 512 (228%) million tons, under the high export extension of the high use scenario. The vast majority of the increase occurs on the shallow draft waterways, while the large percentage increase on the coasts is attributable to the conversion of coastal power plants from oil and natural gas to coal.

Foreign transport of coal increases from 56 million tons in 1977 to 111 million tons under the baseline scenario. Under the bad energy and high use scenarios, the 2003 total is 158 million tons. Under the high coal export scenario, the total is 293 million tons, an increase of 423% over 1977.

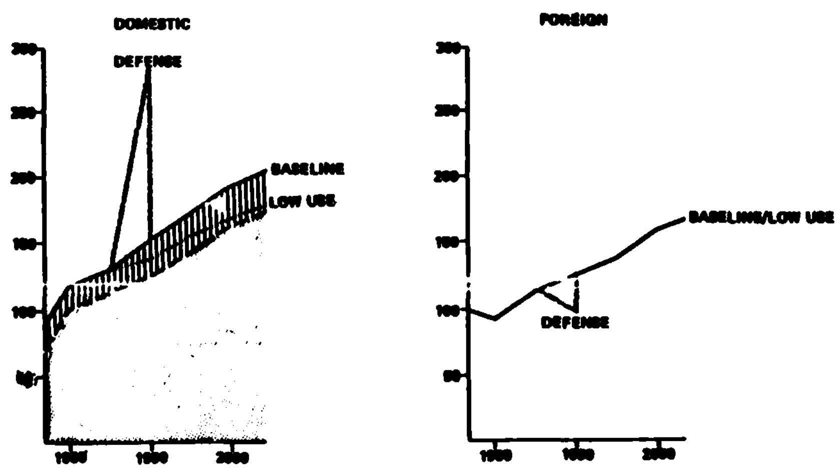
Detailed regional breakdowns of these forecasts are shown in Exhibit VII. The greatest area of growth occurs on the Ohio River. The greatest percentage growth is found on the Tennessee, the Mobile River and Tributaries, Lower Upper Mississippi, Lower Mississippi, and Gulf Coast East. The growth in these latter regions is attributable in part to synfuel plants. Also the Great Lakes/St. Lawrence Seaway and Middle Atlantic tonnage grow significantly.

METALS

Figure V displays the unconstrained forecasts of waterborne tonnage in support of the metals industry, divided into domestic and foreign components.

FIGURE V

UNCONSTRAINED FORECAST OF WATERBORNE
METALS TONNAGE 1977-2003
(MILLIONS OF SHORT TONS)



BASELINE – SHALLOW DRAFT (INCLUDES LOCAL MOVEMENTS WITHIN PORTS).

BASELINE – GREAT LAKES/SEAWAY (INCLUDES COASTAL).

Source: NWS, Evaluation of the Present Navigation System 1981.

The unconstrained baseline forecast of domestic tonnage increases 130% from 90 million tons in 1977 to 207 million tons in 2003. Most of this tonnage growth is on the Great Lakes. The dramatic increase in waterborne tonnage, however, comes under the defense scenario with nearly a doubling of transportation needs to support a long conventional war effort. Iron ore traffic is the principal commodity affected.

Foreign imports of iron ore and steel products make up the majority of the import/export tonnage. These are projected to be extremely stable except in the event of a prolonged conventional war which curtails imports of both ores and finished products.

Exhibit VIII shows the forecast broken down by NWS region. Clearly the bulk of the tonnage increase is on the Great Lakes/ St. Lawrence Seaway, with more modest increases on the Lower Mississippi, Illinois Waterway, the Gulf Coast West, Mobile River and Tributaries and on the Middle Atlantic. All of these are locations with steel-making facilities.

CHEMICALS/
FERTILIZER

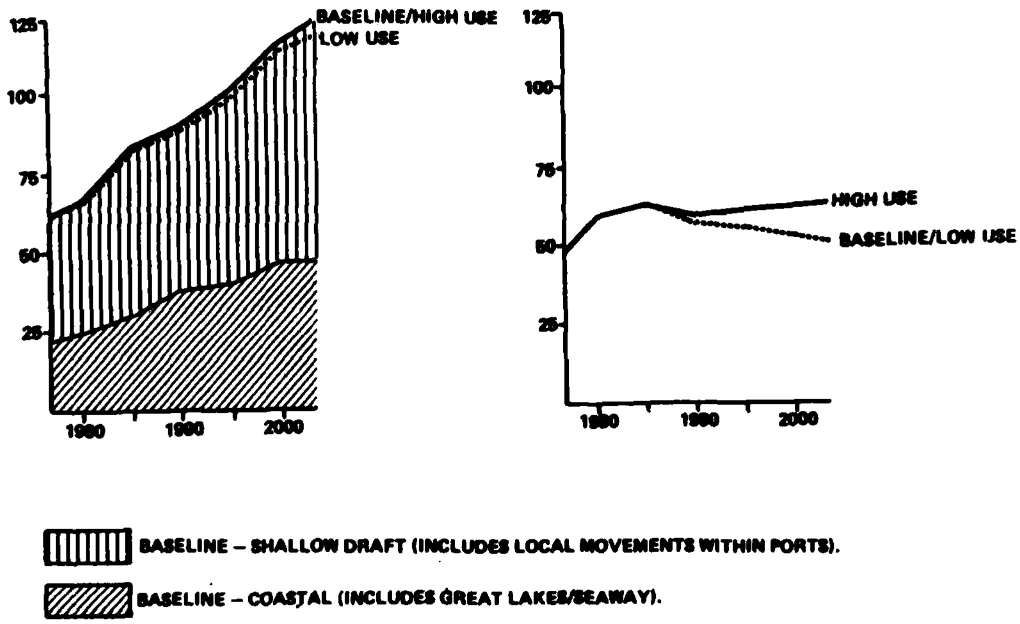
Figure W on the following page displays the combined chemicals and fertilizer industry forecast for waterways transportation needed from 1977 to 2003.

FIGURE W

UNCONSTRAINED FORECAST OF WATERBORNE

CHEMICALS/FERTILIZER TONNAGE 1977-2003

(MILLIONS OF SHORT TONS)



Source: NWS, Evaluation of the Present Navigation System 1981.

Domestic chemicals and fertilizer traffic is projected to increase substantially under the baseline scenario, from 64 million tons in 1977 to 124 million tons in the year 2003 (94%). Most of the absolute increase in tonnage is in the shallow draft distribution of chemicals and fertilizer from the Gulf Coast up the Mississippi River. However, there is a significant increase in domestic coastal traffic as well.

Foreign import/export tonnage is projected to increase modestly from 1977 to 1985 under all scenarios as phosphate rock exports peak. After 1985, declining phosphate rock exports cause total chemicals and fertilizer commerce to return to 1977 levels in 2003

under the baseline and low use scenarios. Flat phosphate rock exports after 1985 (under the high use scenario) cause total chemicals and fertilizer foreign commerce to increase modesty (29%) from 1977 to 2003.

Exhibit IX shows the regional share of the projected traffic. Major increases in chemicals/fertilizer tonnage are expected to be handled all along the Mississippi, the Ohio, and Illinois Rivers, and the Gulf Intracoastal Waterway and Middle Atlantic Coast.

FOREST PRODUCTS

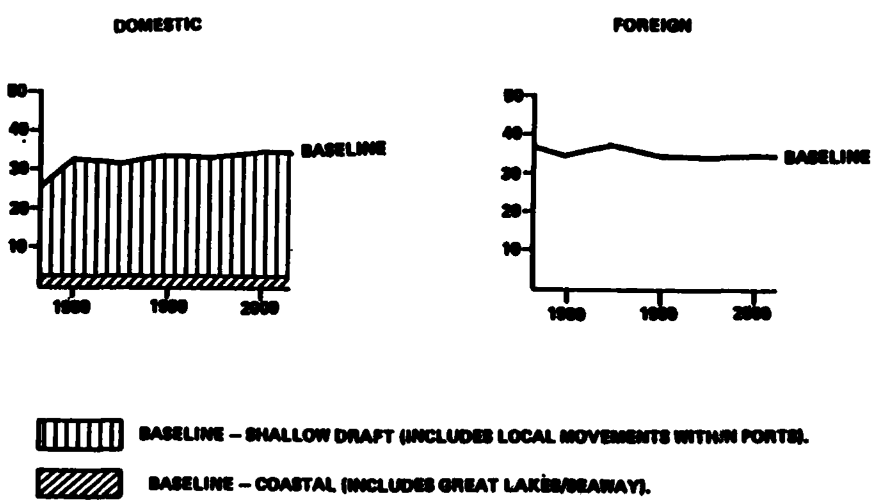
Figure X shows the projected tonnage of forest products available for water transportation. For this commodity, there is no variation from one forecast to another, so only the baseline scenario is shown.

FIGURE X

UNCONSTRAINED FORECAST OF WATERBORNE

FOREST PRODUCTS TONNAGE 1977-2003

(MILLIONS OF SHORT TONS)



Source: IWR, Evaluation of the Present Navigation System, 1981.

Forest products tonnages available for domestic water transportation are expected to grow only modestly over the forecast

period from 27 million tons in 1977 to 36 million tons in 2003. Foreign tonnages are projected to decline slightly.

These forecasts assume the continuation of existing movements of logs and pulp out of the Northwest down the Columbia-Snake Waterway and along the West Coast. However, they project that essentially all of the tonnage produced in southern and midwestern mills will be handled by rail and truck.

Detailed regional forecasts are broken down in Exhibit X.

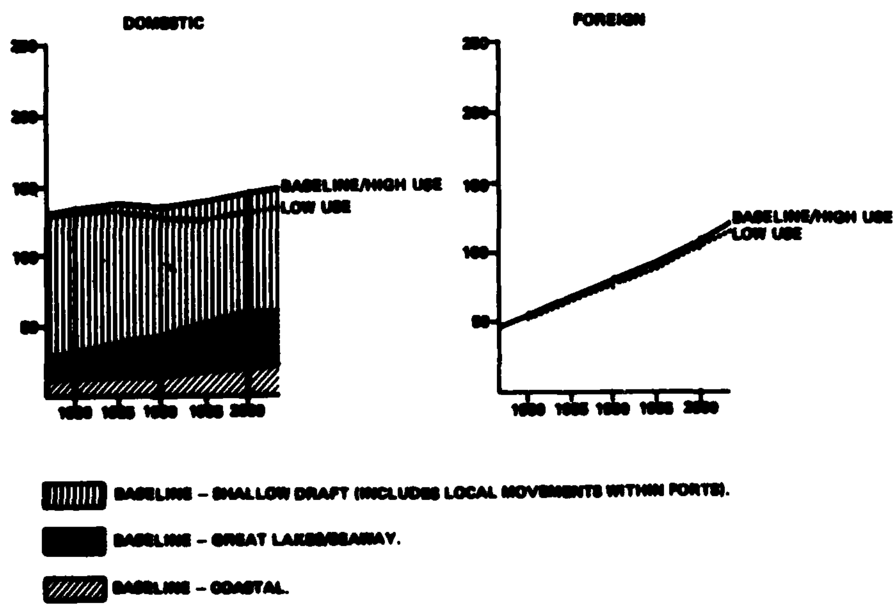
OTHER COMMODITIES

Other commodities include general cargo (including containers) handled on the coasts, sand and gravel, salt, scrap, and cement. The forecasts for each of these commodities were prepared individually but are combined in the graphs shown in Figure Y below.

FIGURE Y

UNCONSTRAINED FORECAST OF OTHER WATERBORNE TONNAGE 1977-2003

(MILLIONS OF SHORT TONS)



Source: IWR, Evaluation of the Present Navigation System 1981.

Total domestic tonnage of these other commodities increases from 129 million tons in 1977 to 148 million tons in 2003 under the baseline scenario. As can be seen from the graph, the only increases take place in coastal and Great Lakes tonnage. Shallow draft tonnage actually declines under the baseline scenario (due to a projected decline in sand and gravel shipments) and falls further under the low use scenario.

Foreign exports and imports are primarily general cargo, non-metallic minerals (salt and clay among others), cement, and iron and steel scrap. These increase from 49 million tons in 1977 to 121 million tons in 2003 under the baseline scenario, an increase of 147%.

Exhibit XI shows regional breakdowns of other commodity forecasts.

SUMMARY

The strong growth in agriculture tonnage is a continuation of an established trend. The more rapid growth in coal is a new trend, reflecting the conversion of oil or gas-fired power plants to coal, the construction of new coal-fired power plants, and increased exports. The decline in petroleum tonnage is a reversal of a post World War II trend. Thus, the total tonnage growth is made up of vastly different patterns by industry and geographic area.

To better understand the geographic impact of this potential waterborne traffic growth, Table 21 on the next page presents the growth in tonnage under the baseline scenario by region based on Exhibit IV.

TABLE 21

TONNAGE GROWTH BY REGION:
BASELINE SCENARIO 1977-1980

REGION	MILLIONS OF TONS 1977	2003	DIFFERENCE	DIFFERENCE
UPPER MISSISSIPPI RIVER	30.9	66.0	35.1	113.6%
LOWER UPPER MISSISSIPPI RIVER	77.5	162.0	84.5	109.0
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	123.6	222.3	98.7	79.8
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	344.4	534.9	190.5	55.3
ILLINOIS WATERWAY	60.4	103.5	43.1	71.3
MISSOURI RIVER	6.7	7.8	1.1	16.4
OHIO RIVER*	172.5	307.5	135.0	78.3
TENNESSEE RIVER	26.5	66.9	40.4	52.4
ARKANSAS RIVER	9.4	14.4	5.0	53.2
GULF COAST WEST	341.3	385.7	44.4	13.0
GULF COAST EAST	108.7	152.1	43.4	40.0
MOBILE RIVER AND TRIBUTARIES*	43.7	119.0	75.3	72.3
SOUTH ATLANTIC COAST	69.8	69.6	(.2)	(.3)
MIDDLE ATLANTIC COAST*	436.8	438.0	1.2	.3
NORTH ATLANTIC COAST	87.4	68.9	(18.5)	(21.2)
GREAT LAKES/SEAWAY	189.9	385.7	195.8	3.1
WASHINGTON/OREGON COAST	68.4	121.2	52.8	77.2
COLUMBIA-SNAKE WATERWAY	43.5	58.6	15.1	34.7
CALIFRONIA COAST	138.3	143.6	5.3	3.8
ALASKA	28.8	86.2	57.4	99.3
HAWAII	15.3	21.5	6.2	40.5
CARIBBEAN	89.8	74.5	15.3	17.0
ELIMINATE OVERCOUNTING	(598.5)	(1024.0)	(425.5)	(71.1)
TOTAL	1914.9	2585.6	670.7	35.0%

The navigation systems in those regions with high growth will be taxed by substantially increased traffic in the next quarter century under essentially all scenarios. Those with an * will be especially burdened if substantially higher levels of coal exports are achieved. Whether the navigation system can accommodate such traffic increases is the subject of the next two sections.

VI - FACTORS AFFECTING WATERWAY TRANSPORTATION CAPABILITY

This section will briefly review the factors which affect the ability of the waterways system to accommodate projected tonnage as discussed in the prior section.

The abililty of the shallow draft inland waterways system and Great Lakes to accommodate the projected traffic is potentially constrained by the physical capacity of the locks which are an integral part of those systems. In addition, the safe operation under increased levels of vessel traffic could also pose concerns on the shallow draft inland waterways, Great Lakes, and coastal approach channels and harbors. Finally, the projections of potential waterborne traffic shown in the prior section are based on the assumption that there will be no major disruption of the basic operating characteristics of the competing modes of transportation. Thus, three issues must be considered to determine whether the national navigation system can accommodate its potential traffic. These are:

- The capacity of the locks to pass the traffic.
- The assurance of reasonably safe vessel operation.
- The maintenance of the navigation system in good working order to maintain the competitiveness of the water transportation mode.

FACTORS AFFECTING LOCK CAPACITY

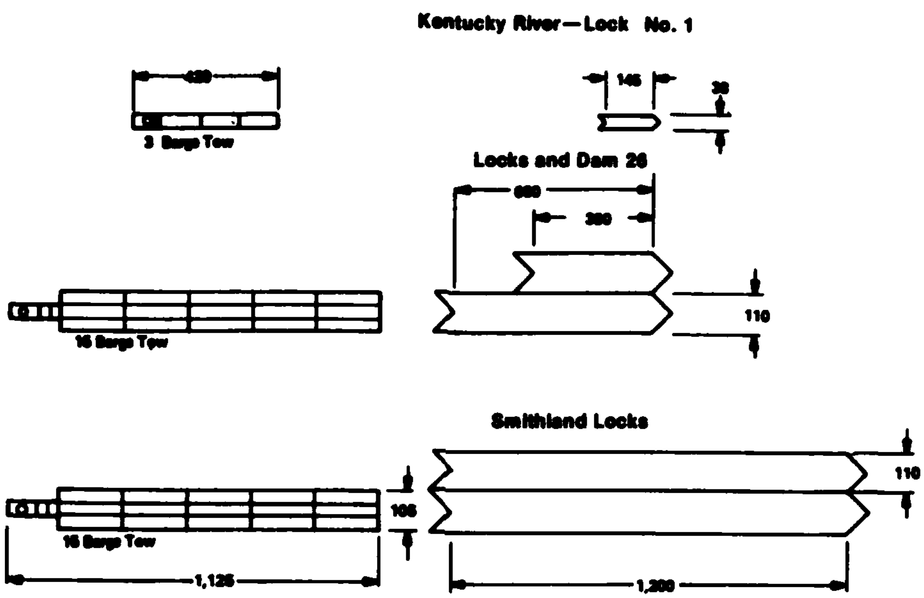
There are over 200 commercially important lock chambers on the shallow draft inland waterways and Great Lakes. (Some locks have more than one chamber. See Figures C, D, and E for locations.) The main purpose of a lock is to allow a vessel or barge tow to pass from one water pool elevation to another, usually at a dam creating the higher pool. Domestic waterways locks involve differences in pool elevation from as little as three or four feet on several waterways to as high as 100 feet or more on several locks of the Columbia-Snake system.

Basic lock equipment is the same regardless of elevation. All locks consist of two sets of gates (one at each end of the chamber) which can open and close to allow the passage of vessels, and a filling/draining system for the chamber. Chamber sizes may range from as small as 38 feet by 145 feet (on the Kentucky River) to as large as 110 feet by 1,200 feet at several sites on the Ohio

and Mississippi Rivers and at the Poe lock between Lake Superior and Lake Huron. See Figure Z for selected lock chamber dimensions.

FIGURE Z

DIMENSIONS FOR SELECTED LOCK CHAMBERS



The basic operation of all locks is essentially the same. One set of gates is opened to allow the entry of the vessel or tow into the lock chamber. The gates are closed and the chamber is filled or emptied as appropriate to raise or lower the water level in the chamber. The other gates are then opened and the vessel exits the chamber. Cycle time ranges from as little as 30 minutes to as much as an hour for single lockages just described.

In many cases, more than one vessel or tow can be accommodated in the chamber during a single lockage cycle. In many other cases, the tow size is too large to be accommodated in a single lockage cycle; therefore, the tow must be broken up into parts, locked through in several cycles, and reassembled on the other side. In the examples presented in Figure Z, the tow sizes for the Kentucky River Lock and Lock and Dam 26 are too large to be accommodated in a single locking cycle. Multiple lockage could take as long as two hours or more.

If more than one tow approaches a lock at approximately the same time, one must wait for the other to be locked through. Queues to pass Lock and Dam 26 on the Upper Mississippi River have exceeded 100 tons. Another complication occurs if there is an imbalance between upbound and downbound traffic at a particular point in time. In this case, vessels would be locked through in one direction but the chamber must be refilled (or emptied) with no vessel present in the opposite direction.

The maximum theoretical capacity of a lock to accommodate vessels and tows would occur if its chamber were completely filled with vessels both ways on each cycle with the lock operating continously. In practice, locks operate at from 5% to 60% of this theoretical level of utilization. The difference between 60% and maximum theoretical utilization of 100% relates to the seasonality of traffic, downtime of the locks, distribution of tow sizes that require lockings of less than full chambers, space devoted to recreation craft, closure of the waterway during the winter, delays entering and exiting chambers which extend cycle time, and others.

The <u>tonnage</u> which can be accommodated by a lock relates to its physical <u>capacity</u> and utilization described above and to the mix of traffic, barge or vessel size, tow size, and depth of loading. If there were no compatible backhauls available, only 50% of barges locked through would be filled with cargo. Where compatible backhauls can be matched up, the percentage of loaded barges increases somewhat above 50% but rarely gets above 65% in practice. If the standard (jumbo) barges are loaded to the full 9-foot channel depth available at most inland locks, they will hold about 1,500 tons of cargo. However, if deeper water levels allow slightly deeper loading, more cargo can be accommodated per lock cycle. If low water levels or shallow channels decrease draft below 9 feet, less cargo can be handled.

Thus, the number of tons that the lock can accommodate is a function not only of its physical characteristics but also of the traffic mix and other operating conditions on the waterway.

FACTORS AFFECTING SAFETY

A significant effort was devoted during the National Waterway Study to the analysis of historical data concerning vessel accidents on the shallow draft waterways and Great Lakes and at ocean ports. This involved extensive analysis of data provided by the Coast Guard and review of significant studies completed by them.

The basic conclusion is that a vessel accident, cargo spill or personal injury could occur virtually at any place or any time. However, there is strong evidence to suggest that the probability of an accident increases rapidly when the following hazards are present:

- Bridges.
- Locks.
- Unusual channel configurations.
- Congested traffic areas.

Bridges with narrow horizontal clearances compared to the sizes of tows or vessels passing through them obviously offer a greater opportunity for navigation error. The analysis of historic accident data and navigation charts reveals that approximately 160 bridges across the nation's waterways can be identified as navigation hazards. In contrast, there are hundreds of bridges across the waterways at which there are no unusually high rates of accidents. Exhibit XII lists the mile-marker locations of hazards to navigation, including restrictive bridges.

Vessels approaching and entering locks (particularly during swift current, foul weather or fog) are more likely to have an accident than when they are in an open channel. Some locks are better designed than others to avoid a high incidence of accidents. There are 14 locks which are hazardous based on historical accident data and a review of navigation charts. These are shown in Exhibit XII.

River bends, junctions, and narrow channels tend to make navigation more difficult. Around bends and at junctions, visibility to see approaching tows is often obscured. Shoaling (the buildup of small sandbars) is also more common at river junctions, increasing the possibility that tows might run aground.

Obviously, the opportunity for collision increases in highly congested harbors and channels. In New Orleans, for instance, literally hundreds of individual vessels and barges operate in the harbor area each day. Highly congested areas are also listed in Exhibit XII.

Improved pilot training, navigation aids, radio communication, and other modern technology, as well as regulation enforcement can reduce the occurrence of accidents both at high probability locations listed in Exhibit XII and at other locations as well.

The likelihood of an environmentally damaging cargo spill is highest under two sets of circumstances: loading/unloading cargo or the occurrence of an accident. Therefore, stricter enforcement of regulations and proper training of personnel will tend to reduce spills during loading and unloading operations. Reduction in the absolute number of accidents due to other causes will tend to also reduce the absolute number of cargo spills, as well.

FACTORS AFFECTING MODAL COMPETITIVENESS

Maintaining the competitiveness of the marine mode for domestic transportation, the competitveness of American exports in world trade, and the landed price for imports requires maintaining the nation's navigation system in good working order.

Cargo carrying capacity is a direct function of the depth to which vessels can be loaded and the width of the vessel or tow that can be accommodated by the channel. Therefore, maintaining channels at authorized or practical dimensions of width and depth is important to maintaining the cargo carrying capacity of the marine mode at historically competitive levels. Failure to adequately dredge in a timely manner to maintain the channel in good working order decreases the carrying capacity of the existing system through light loading of vessels, and increases the cost per ton handled. This issue is important for Great Lakes commerce, shallow draft inland waterways, and ocean ports as well.

Average speed of vessel or tow over the length of a trip can be adversely affected by inadequacies in the navigation system. If a lock is congested so that a tow or vessel must wait before passing through, the average speed on that trip is reduced from its normal level. Congested traffic areas, particularly in conjunction with the hazards to navigation discussed previously, contribute to slower than normal speeds of transit. Slower average speeds decrease the utilization of fixed capital investment in vessels and barges, and increase labor costs per mile. Therefore, slower than normal speeds contribute directly to increased costs per ton of cargo handled. Reduced speeds are a problem in the Great Lakes/St. Lawrence Seaway, the shallow draft inland waterways, and many coastal ports.

Both cargo carrying capacity and speed directly affect the cost of marine transportation as reflected in the average cost per ton-mile. This cost has been used as an index of modal competitiveness in the evaluation of the present navigation system, discussed in Section VII.

MAINTAINING CAPABILITY

There are two additional issues which affect the ability of the Corps of Engineers to maintain the nation's navigation system in good working order. These are dredging and rehabilitation of existing structures.

Because of general increases in inflation (particularly in fuel) and more stringent environmental constraints on dredged material disposal, **the real cost of dredging is rising far more rapidly than the general rate of inflation.** Thus, if the budget allocated for dredging maintenance is only increased at the rate of inflation, then historical levels of dredging will tend to consume an increasing share of the navigation budget. A projection made during this study suggests that the real growth of adequate dredging costs will be about 2.2% per year greater than the general rate of inflation. This means that adequate dredging in the year 2003 might cost as much as $150 million more (in 1977 dollars) than it does today. This would represent nearly a doubling of the dredging budget in real terms over today's levels.

Many lock structures on major waterways are now becoming quite old. Many were built in the 1930s and will be more than 60 years old by the turn of the century. Such ancient structures are subject to normal deterioration and wear and tear, making them more subject to potential failure than newer structures.

Therefore, the rehabilitation of the structures to keep them sound and in good working order will require investment that is beyond normal maintenance and which does not increase their cargo handling capability. Such expenditures have been rare in the Corps of Engineers' budget in the past but will become far more common as the 21st century approaches. By the year 2003, this item could consume as much as $126 million per year (in 1977 dollars), up from about $37 million in the Corps' 1977 budget. A small portion of this increase, of course, reflects the increasing cost (in real terms) of undertaking rehabilitation.

Thus, both the costs of maintenance dredging and rehabilitation, essential (but mundane) actions, are expected to increase faster than the rate of inflation in the future, posing a challenge to managers of the navigation system at a time when financial resources are becoming more scarce.

VII - EVALUATION OF THE PRESENT NAVIGATION SYSTEM

The major thrust of this study has been to evaluate the capability of the present navigation system to handle the projected growth of waterborne traffic. This section will review the results of that evaluation and present a list of construction and other needs which must be met for the system to effectively accommodate the projected traffic.

The objective of the analysis of the present navigation system was to determine the limits of the ability of the present system to accommodate the projected potential traffic. Thus, it did not simply take a "business as usual" viewpoint of the capability of the present system. Instead, the analysis has assumed the application of all logical, known technology and management techniques to squeeze the maximum capability from the present navigation system before suggesting the need for major new investments.

The capability of the present navigation system to handle the projected tonnage will be evaluated in three components: lock capacity, safety, and linehaul cost (as an indicator of modal competitiveness).

LOCK CAPACITY

(a) Methodology

The NWS forecasts for each of the six scenarios were used to estimate the expected upbound and downbound tonnage of each NWS commodity for each of more than 200 commercially significant chambers in the navigation system. Based on these detailed projections of traffic mix, estimates were prepared of future average tow size at each lock, the estimated lading of each vessel or barge at each lock, and the percentage of barges and vessels which were loaded (based on potential backhaul match-up by commodity). Based on the physical characteristics of each lock (as contained in the 1976 data base from the Corps' PMS and other special studies) and the traffic flow projections, the capacity of each lock was estimated based on historical operating practices.

Adjustments to the historical lock operating data were then made to reflect the assumed implementation of a logical set of inexpensive management procedures to improve lock utilization. Generally, these actions tend to either "pack" more vessels into the lock chamber during each cycle or decrease the elapsed time necessary to complete each locking cycle. **The resulting estimate**

of lock capacity thus represents an assumed limit of the present structure given the projected traffic mix. Note that such actions are consistent with the existing Corps policy and would be part of any logical management strategy for the future. However, the lock capacity limits presented in this section may not match prior estimates of capacity from other studies, which were based on different assumptions.

This process for estimating lock capacity limits was applied consistently and evenhandedly to every commercially significant lock included in the navigation system. Based on this process, potential lock capacity shortfalls in 2003 have been identified under each of the potential scenarios of the future.

(b) Primary Constraints

Those locks which appear to be primary constraints are shown in Table 22.

TABLE 22

PRIMARY CONSTRAINTS TO NAVIGATION DUE TO INADEQUATE LOCK CAPACITY (1)

REGION / LOCK NAME	EARLIEST CONSTRAINING YEAR(2)	MILLIONS OF TONS OF CAPACITY SHORTFALL IN 2003: BASELINE	HIGH USE/ DEFENSE(3)	LOW USE	BAD ENERGY	HIGH COAL EXPORTS
LOWER UPPER MISSISSIPPI						
LOCK AND DAM 26	1985	24	24	14	30	24
GREAT LAKES/SEAWAY						
WELLAND CANAL (5 LOCKS)	1985	5	16	0	18	16
OHIO RIVER						
GALLIPOLIS	2000	7	9	3	2	9
UNIONTOWN	2000	0	11	0	12	25
MOBILE RIVER & TRIBUTARIES						
DEMOPOLIS	1995	*	10	1	1	20
ELIMINATE OVERCOUNTING(4)	-	0	(8)	(3)	(5)	(17)
TOTAL		36	62	15	58	77

Notes: * Less than 500,000 tons.
(1) Locks where capacity is reached or exceeded by projected waterways tonnage before or by 2003.
(2) Earliest year in which lock capacity is reached or exceeded by projected tonnage under one or more of the NWS scenarios.
(3) In 2003 defense is same as high use. At height of hypothesized war in 1990, the Sault St. Marie Lock is constraining with shortfall of 67 million tons.
(4) Eliminates the double counting of shortfalls at multiple locks.

Source: NWS, *Evaluation of the Present Navigation System*, 1981.

There is one primary constraining point in the navigation system which appears under <u>all</u> <u>scenarios</u> of the future:

- **Lock and Dam 26 on the Mississippi River near Alton, Illinois.**

This is true even after the currently authorized replacement of the existing dam and chambers with a new dam and single 1,200-foot by 110-foot chamber.

Four additional navigation points are constrained by lock capacity under at least three scenarios:

- Five locks on the Welland Canal between Lake Erie and Lake Ontario.

- Gallipolis Lock on the Ohio River near Huntington, West Virginia.

- Uniontown Lock on the Ohio River near Mt. Vernon, Indiana.

- Demopolis Lock on the Tombigbee-Warrior River system in Alabama.

In addition, at the height of the hypothesized conflict in the defense scenario, the Sault St. Marie Locks between Lakes Superior and Huron would experience a capacity shortfall of 67 million tons per year, mostly iron ore for steel production.

Based on this analysis, a total of ten locks has been identified as being primary constraints to navigation under at least one scenario of the future.

Table 23 on the next page shows the estimated capacity shortfall by industry for the two extreme scenarios.

TABLE 23

ESTIMATED LOCK CAPACITY SHORTFALL BY INDUSTRY

INDUSTRY	MILLIONS OF TONS OF CAPACITY SHORTFALL	
	LOW USE SCENARIO	HIGH COAL EXPORT SCENARIO
AGRICULTURE	8	20
METALS	1	9
COAL	3	35
PETROLEUM	1	4
CHEMICALS/FERTILIZER	2	6
FOREST PRODUCTS	0	0
OTHER	1	3
ROUNDING ERROR	(1)	0
TOTAL	15	77

The primary lock constraints would impair the navigation system from accommodating sixteen million tons of potential waterborne cargo in 2003 under the low use scenario -- mostly agricultural exports which would not pass through Lock and Dam 26. Under the high coal export scenario, the capacity shortfall is estimated to be 77 million tons in 2003 -- made up primarily of export grain and coal. This represents a shortfall of up to 30% of the grain which would potentially move through Lock and Dam 26 in 2003 and more than 30% of potential incremental coal exports projected under the high coal export scenario. Thus failure to provide the adequate capacity at these key locks would significantly disrupt normal logistics of the important grain and coal export industries. As a result, some of the grain and coal may not be grown or mined at all -- creating an absolute loss to the nation's economy. At a minimum, the unaccommodated traffic would be forced to move via an alternative, higher priced mode of transportation. This study has not included a detailed analysis of potential traffic diversion. However, a general indication of impact can be gained if one assumes the cost of moving 77 million tons of cargo for the average marine length of haul of 400 miles at a penalty of 5 mills per ton-mile. Under the high coal export scenario, this assumed economic penalty would total about $150 million per year in 1977 dollars.

(c) Secondary Constraints

If all ten primary constraining locks were replaced in the years shown in Table 22, then all the projected traffic would be accommodated by them under each scenario. However, such an increase in traffic would create constraints at eleven additional locks in the navigation system under at least one scenario of the future. These are shown in Table 24.

TABLE 24

SECONDARY CONSTRAINTS TO NAVIGATION DUE TO INADEQUATE LOCK CAPACITY(1)

REGION / LOCK NAME	EARLIEST CONSTRAINING YEAR(2)	MILLIONS OF TONS OF CAPACITY SHORTFALL IN 2003				
		BASELINE	HIGH USE/ DEFENSE(3)	LOW USE	BAD ENERGY	HIGH COAL EXPORTS
ILLINOIS WATERWAY						
LA GRANGE	2000	7	7	2	11	7
PEORIA	2003	3	2	0	7	2
MARSEILLES	2000	1	4	1	1	4
UPPER MISSISSIPPI						
LOCK AND DAM 22	2003	1	1	0	5	1
OHIO RIVER						
NEWBURGH	2003	0	0	0	0	1
MCALPINE	2003	0	0	0	0	1
MOBILE RIVER AND TRIBUTARIES						
OLIVER	1990	0	6	1	2	14
WARRIOR	2000	0	3	0	0	12
HOLT	2000	0	*	0	0	9
COFFEEVILLE	2000	0	0	0	0	8
BANKHEAD(4)	2003	0	0	0	0	*

* Less than 500,000 tons.

Notes: (1) Locks where capacity would be reached or exceeded by 2003 if adequate capacity is provided at all locks shown in Table 22.
(2) Earliest year in which lock capacity would be reached or exceeded under one or more scenarios.
(3) Defense and high use scenarios are identical in 2003. Marseilles is a constraint at the height of the hypothesized war in 1990.
(4) Bankhead would become constraining under the high coal export scenario only if all other constraints on the Warrior-Tombigbee System are relieved.

Source: NWS, Evaluation of the Present Waterway System, 1981.

The additional traffic accommodated if Lock and Dam 26 were expanded would meet a capacity shortfall at the La Grange, Peoria, and Marseilles Locks on the Illinois Waterway, and at Lock and Dam 22 on the Upper Mississippi River, under virtually all scenarios of the future.

Replacement of Demopolis on the Tombigbee-Warrior system would result in Oliver lock on the Warrior River near Tuscaloosa becoming a constraint.

Under the high coal export scenario, a number of additional locks could become secondary constraints. The additional traffic from the replacement of Uniontown would create a modest shortfall at Newburgh and McAlpine Locks on the Ohio River. The additional traffic from the replacement of Demopolis would create shortfalls at the Warrior, Holt and Coffeeville locks on the Tombigbee-Warrior system. If these were expanded, Bankhead would then become a constraint under the high coal export scenario.

(d) Potential Constraints

In addition to the six formal scenarios of the future, a seventh set of potential traffic projections was prepared to test whether or not additonal locks could become constraints under some conditions. These projections included a potpourri of "miscellaneous" adjustments to the basic forecasts. For instance, during the analysis, it was discovered that there had been underreporting of historical tonnages on some waterways. These were corrected based on data supplied separately by the individual Corps Districts involved. As a result, one additional lock was identified as a potential secondary constraint - the Montgomery Lock on the Ohio River near Pittsburgh. The Kentucky Lock on the lower Tennessee River would have also become a potential constraint except that there is an alternative routing through the Barkley Lock and diversions would be unlikely.

Similarly, failure of existing data bases to capture the movement of fishing and offshore oil supply boats and some foreign traffic at the Inner Harbor Lock in New Orleans understates the current throughput at that facility. When added to the reported traffic, this additional activity makes this lock constraining also.

Lock and Dam 52 on the Ohio River near Paducah, Kentucky was not included as a constraining lock because the dam can be lowered to permit open passage of tows about 60% of the time. However,

if peak traffic periods correspond to nonopen pass periods or extended droughts occur, then the lock could potentially be constraining.

Finally, the Corps District in Portland, Oregon has projected a new movement of sand and gravel affecting the Bonneville Lock on the Columbia River above Portland. If their projected increases were to take place, then Bonneville Lock would also be constrained.

In summary, between now and the year 2003 (the time horizon for this study), only 25 of the over 200 commercially significant chambers in the navigation system are projected to pose a capacity constraint to potential traffic. These are summarized in Table 25 below and shown geographically on Figure AA for reference.

TABLE 25

SUMMARY OF CONSTRAINING LOCKS IN 2003

CONSTRAINT	UNDER FOUR OR MORE SCENARIOS	UNDER TWO OR THREE SCENARIOS	UNDER HIGH COAL EXPORT ONLY	UNDER SOME CIRCUMSTANCES ONLY
PRIMARY	MISSISSIPPI L & D #26 WELLAND CANAL (5) GALLIPOLIS DEMOPOLIS	UNIONTOWN		SAULT ST. MARIE[1]
SECONDARY	LA GRANGE PEORIA MARSEILLES MISSISSIPPI L & D #22 OLIVER	WARRIOR HOLT	NEWBURGH MCALPINE COFFEEVILLE BANKHEAD	
POTENTIAL	INNER HARBOR	MONTGOMERY		OHIO L & D #52[2] BONNEVILLE[3]

Notes: (1) To prepare for a defense emergency.
(2) Under low flow conditions.
(3) Based on Corps' Feasibility Report of January 1977.

(e) Congested Locks

In addition to those locks which actually reach capacity before the year 2003, there are a number of locks that will become highly utilized and thus increasingly congested by the turn of the century. Many of these are likely to reach capacity after 2003. Table 26 shows all locks with computed delays of 60 minutes or more under the baseline scenario in 2003.

FIGURE AA

POTENTIALLY CONSTRAINING LOCKS IN 2003

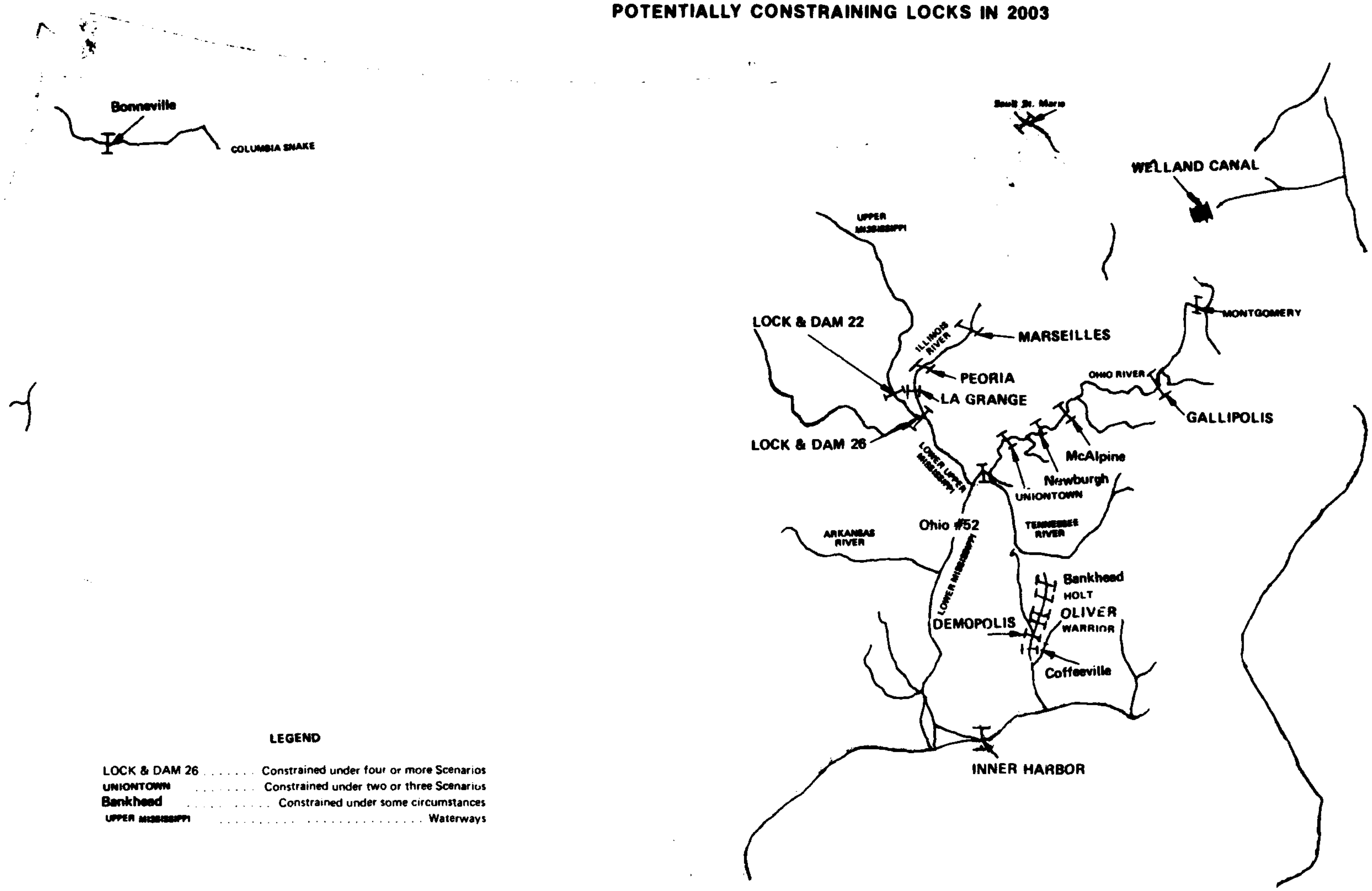


TABLE 26

CONGESTED LOCKS IN 2003

REGION LOCK NAME	MILLIONS OF TONS CAPACITY (1)	PROJECTED USE (1)	CHAMBER UTILIZATION (1)	RANGE OF CHAMBER UTILIZATION IN 2003 UNDER OTHER SCENARIOS (PERCENT)
UPPER MISSISSIPPI RIVER				
L AND D 15	53.8	33.9	63%	57 - 68%
L AND D 16	52.4	37.7	72	65 - 77
L AND D 17	54.1	39.3	73	65 - 78
L AND D 18	54.7	40.9	75	67 - 81
L AND D 19	54.5	44.7	82	75 - 88
L AND D 20	58.8	45.7	78	70 - 84
L AND D 21	59.0	47.4	80	72 - 86
L AND D 24	59.1	50.1	85	76 - 91
L AND D 25	58.9	51.6	88	76 - 92
LOWER UPPER MISSISSIPPI				
L AND D 27	155.5	124.0	80	72 - 83
ILLINOIS WATERWAY				
STARVED ROCK	44.7	39.1	88	87 - 95
DRESDEN ISLAND	46.3	33.3	72	71 - 77
LOCKPORT	39.1	32.8	84	83 - 91
OHIO				
DASHIELDS	39.4	29.8	76	73 - 82
EMSWORTH	36.6	29.4	85	81 - 93
TENNESSEE RIVER				
KENTUCKY	41.3	34.7	84	67 - 100 (2)
GULF COAST WEST				
HARVEY	12.5	10.4	83	73 - 87
ALGIERS	35.2	31.1	88	77 - 92

Notes: (1) Baseline Scenario.
(2) Projected Use would exceed capacity but would not divert from water due to an available alternative routing.

Source: Delays at Locks (NWS Working Papers for Evaluation of the Present Navigation System).

Although these locks do not pose potential capacity constraints this century, they do have important impacts on the capability of the navigation system.

- Congested traffic areas pose safety hazards.

- Congestion-induced delays increase linehaul costs and reduce modal competitiveness.

- Further increases in traffic after 2003 could place them on the constraining list.

The first two of these issues will be discussed on the following pages. The third is beyond the scope of this study.

NAVIGATION SAFETY

As shown in Exhibit XII, there are nearly 200 sites on the navigation system which are particularly hazardous to navigation safety. These include narrow bridges, some locks with unusual conditions, unusual channel configurations, and congested traffic areas. These areas will continue to create hazardous navigation conditions until action is taken to reduce risks. In addition, these existing hazardous areas will tend to become worse as there are increases in traffic, as lock delays increase, as tow sizes increase relative to the maximum that can be accommodated by the channel and locks, and as the share of hazardous commodities increases. Table 27 shows those regions where there are significant increases in these contributing conditions, using the baseline scenario for reference.

TABLE 27

REGIONS WITH POTENTIAL INCREASE IN CONDITIONS CONTRIBUTING TO HAZARDOUS NAVIGATION(1)

	POTENTIAL TRAFFIC INCREASE 1977-2003 (MILLIONS OF TONS)	LOCK DELAY IN 2003 (HOURS)	AVERAGE TO MAXIMUM TOW SIZE (PERCENT)	SHARE OF HAZARDOUS COMMODITIES (PERCENT)
GREAT LAKES/SEAWAY	191	6.8	-	3
BATON ROUGE TO GULF	167	-	33	35
OHIO RIVER	129	4.9	63	14
MOBILE RIVER AND TRIBUTARIES	75	3.5	100	16
LOWER UPPER MISSISSIPPI	60	3.9	39	17
ALASKA	57	-	-	89
WASHINGTON-OREGON COAST	53	-	-	51
GULF COAST EAST	43	0.4	60	34
GULF COAST WEST	42	0.2	55	65
TENNESSEE RIVER	37	1.5	49	15
ILLINOIS WATERWAY	30	8.4	43	16
UPPER MISSISSIPPI RIVER	24	21.7	64	13

Note: (1) Based on baseline scenario and the present navigation system without lock expansion or other actions.

Source: NWS, Evaluation of the Present Navigation System, 1981.

If no steps are taken to mitigate the effects of these trends, safety problems will tend to increase by the turn of the century in the areas shown in the preceding table.

Substantial increases in traffic and lock congestion could potentially aggravate bridge clearance problems on the Great Lakes/St. Lawrence Seaway. In the Baton Rouge to Gulf segment of the Mississippi River, rapid increases in traffic and the interaction of shallow draft and deep draft vessel traffic will increase safety hazards. Similarly, increases in traffic on the Ohio, Mobile River and the Mississippi River between the Illinois Waterway and Cairo, Illinois will tend to increase the potential for safety problems at key hazardous points on those waterways. On the Alaska and Washington/Oregon coasts, a possible problem is potential spills of Alaskan crude oil. On the Gulf Coast Waterways east and west of New Orleans, a high share of hazardous commodity traffic coupled with narrow channels tend to accentuate the potential for safety problems. On the Tennessee River, Illinois Waterway and Upper Mississippi, increased traffic will make navigation of narrow bridge structures more difficult.

Actions to reduce navigation hazards would include a program of (relatively low cost) improvements to navigation aids (lights, buoys, etc.) and the addition of bumpers and protective mooring structures at key hazardous points to assist pilots in navigating these channel stretches safely. A more complete mitigation of some navigation hazards would include removal of unused bridges and other structures and redesign of bridge spans (often as a part of a normal replacement and upgrading) to allow greater clearances. However, implementation of these actions could be complex because of multiple Federal and local governmental jurisdictions and private interests involved and lack of clear priority and funding to improve safety.

Thus, the second set of needs for the nation's navigation system to operate effectively in the quarter century ahead is a coordinated program of safety hazard removal/mitigation. This should concentrate on the approximately 200 locations shown in Exhibit XII with particular emphasis on the regions shown in Table 27.

LINEHAUL COSTS

For e :h segment of the waterway and for each commodity group, estimates of the average cost of water transportation linehaul (per ton-mile) were made for 1977. These estimated costs per ton-mile were forecasted for the year 2003 based on projected changes in traffic mix, real fuel cost increases, a fuel tax per Public Law 95-502, gains in fuel efficiency, and delays at locks. Where real cost increases are significant over the next quarter of a century, the marine mode is at a potential competitive disadvantage for carrying the traffic projected for it under the various NWS scenarios. The potential traffic forecasts, used throughout this study, assume that the marine mode cost increases parallel those of competing modes. Therefore, where linehaul cost increases are significantly above average, there may be a possibility thac traffic levels would not reach the potential forecast in the scenarios.

NWS regions with significant linehaul cost increases are shown in Table 28. Overall average real increase in costs for all segments is about 35%.

TABLE 28

REGIONS WITH SIGNIFICANT INCREASES IN WATER TRANSPORTATION COSTS(1)

REGION	MILLS PER LINEHAUL TON-MILE(2) 1977	2003	PERCENT CHANGE 1977 TO 2003
UPPER MISSISSIPPI RIVER	7.5	10.8	44%
LOWER UPPER MISSISSIPPI	8.1	11.5	42
MISSOURI	16.2	22.6	40
GULF COAST WEST	11.4	16.6	46

Notes: (1)Based on the baseline scenario conditions and the present navigation system with no lock expansion. Similar results occur under other scenarios.
(2)1977 dollars.

Source: NWS, Evaluation of the Present Navigation System, 1981.

On the Mississippi River, linehaul costs are projected to increase at a greater than average rate primarily because of congestion at Lock and Dam 26 on that waterway. This cost increase may be even greater than shown in the table if operators also have to resort to light loading to operate safely with

reduced levels of dredging on that waterway. The cost increases on the Missouri are primarily the result of higher than average fuel consumption required on the Missouri and the projected rapid increase in the real cost of fuel. The increases on the Gulf Coast west of New Orleans are primarily the result of high horsepower needs and congestion.

The potential traffic most likely to be diverted as a result of these high linehaul cost increases would be grain moving down the Mississippi River for export and chemicals moving along the Gulf Coast.

To maintain linehaul costs for the marine mode at historically competitive levels requires:

- **Timely expansion of congested locks which cause delays.**

- **Adequate maintenance of channels at their historic width and depth levels.**

MAINTENANCE OF THE NAVIGATION SYSTEM

Besides maintaining adequate lock capacity and mitigating hazardous navigating conditions, the physical structures of the navigation system must be maintained in good working order. This includes:

- Maintenance and occasional rehabilitation or replacement of existing locks and other structures when they become deteriorated or obsolete.

- Dredging of channels from time to time to remove sediment and maintain them at their operating widths and depths.

SUMMARY OF NEEDS

Based on the above discussion, a summary of navigation system needs has been developed.

For the present waterway system to accommodate all of the traffic projected for it in the year 2003 (safely and at a linehaul cost consistent with past modal relationships), the

following minimum needs must be met under four or more scenarios of the future:

1. Increase Physical Lock Capacity. The physical capacity at thirteen locks must be increased via major construction (Lock and Dam 26, five locks on the Welland Canal, Gallipolis, Demopolis, La Grange, Peoria, Marseilles, L + D 22 on the Mississippi and Oliver. Pending clarification of data problems, the Inner Harbor lock in New Orleans could be added to this list.

2. Increase Lock Throughput Capability. The throughput capacity at other congested locks must be increased by taking one or more inexpensive structural or nonstructural actions as appropriate to increase capacity to the practical limit of the existing structure.

3. Mitigate Safety Hazards. Modest investments must be made to construct fenders or mooring cells at selected bridges and locks, remove hazards to navigation, place additional navigation aids, and enhance vessel traffic control systems in congested areas. This should improve the safety at about 200 points in the system.

4. Maintain the Navigation System. The present navigation system must be kept in good working order, including timely rehabilitation of aging structures and adequate dredging of channels and harbors to maintain the competitiveness of the marine mode domestically and American goods in world commerce.

Under one or more of the scenarios of the future, additional lock capacity would be required to ensure continued effectiveness of the navigation system. This includes increases in lock capacity at eight additional sites.

- Uniontown	- Newburgh	- Bankhead
- Warrior	- McAlpine	- Sault St. Marie
- Holt	- Coffeeville	(Defense scenario only)

In addition, potential action could be needed at the Montgomery, Ohio #52, and Bonneville locks under some circumstances.

Alternative strategies for meeting these needs, and for improving the navigation system are identified and evaluated in Section VIII.

VIII - EVALUATION OF ALTERNATIVE STRATEGIES

To meet the navigation system's needs identified in the previous section, the Congress and the Corps of Engineers have a wide range of possible options available to them. To evaluate the likely effectiveness of alternative courses of actions, their costs, and their impacts, four alternative strategies have been defined. A strategy consists of a statement of management philosophy and a set of management policies by which individual investments and other expenditures are chosen for implementation. The strategies presented in this report are for comparison of alternative courses of action only and are not recommendations for specific actions.

Potential expenditures to meet the needs of the nation's navigation system fall into the following categories:

1. Completion of the "Present" System. Throughout this study it has been assumed that the "present" navigation system would be completed. This consists of the actual system in place in December 1978 plus authorized and funded additions. These include completion of the:

- Tennessee-Tombigbee waterways system.
- Red River project.
- Replacement 1,200-foot chamber at Lock and Dam 26 on the Mississippi River.
- 1,200-foot chamber at Vermilion on the Gulf Intracoastal Waterway.
- Replacement lock chambers for Locks 6 and 8 on the Ouachita.
- Second chamber at Pickwick on the Tennessee River.
- 12-foot channel from Cairo, Illinois to Baton Rouge.

These actions to complete the "present" system are estimated by the Corps to cost $2,382,778,000 in 1977 dollars. Costs used in valuing the strategies in the NWS analysis totaled $3,070,647,000 in 1977 dollars based on the programming of investment between 1977 and 2003 and an assumed 1.25% real cost inflation rate for construction.

2. Operations and Normal Maintenance of Existing Locks and Other Structures. This expenditure is assumed to be constant (in 1977 dollars) at the five-year average level of $126,037,000, plus increments associated with completion of the present system. This covers operation of locks and other Corps facilities and normal preventitive maintenance of Corps-maintained structures. Increases or decreases in this amount would be programmed only if specific facilities or segments are added to or subtracted from the navigation system.

3. Managerial Actions To Increase Lock Throughput Capability. Throughout the strategy analysis, it has been assumed that low cost managerial actions have been taken at all congested locks to maximize throughput of existing structures. No public costs have been included for these actions, however, as they are believed to be small.

4. Maintenance Dredging of Channels. The five-year average maintenance dredging by the Corps totaled 288,981,600 cubic yards per year. At 1977 costs, this consumed $205,633,000 of the Corps budget. In future years, environmental dredged material disposal regulations and increased energy costs will inflate the cost of dredging at a rate greater than the overall rate of inflation. These costs have been estimated for each segment of the navigation system and applied to the above five-year dredging volumes. Increases or decreases in volumes are made only where segments are added or removed from the navigation system.

5. Rehabilitation/Replacement of Ongoing Locks and Other Structures. The estimated budget needed to adequately maintain the major locks and other structures under Corps responsibility was developed based on the first cost, age and other characteristics of each facility and inflated for real increases in construction costs after 1977. This budget was adjusted for inclusion or exclusion of individual structures or segments in the navigation system.

6. Structural Actions To Increase Lock Capacity. Exhibit XIII shows the projected construction cost (in 1977 dollars) for increasing capacity of all locks potentially needed to meet the minimum requirements shown in the prior section. Also shown are the costs for optional expansion/replacement of locks considered under Strategy IV (discussed later).

7. Inexpensive Actions To Mitigate Safety Hazards. Exhibit XIV shows the one-time construction and ongoing maintenance and operations costs for implementing actions to mitigate navigation hazards at approximately 200 identified points in the navigation system.

The remainder of this section will define and explain four potential management strategies for the navigation system. Each will be evaluated by evenhandedly applying to the present system the logical actions which might be taken under each strategy between now and 2003 for each of the six scenarios. Based on the data just presented, the estimated costs associated with each strategy will be presented and its effectiveness at meeting the minimum needs will be discussed. A comparison of the strategies is presented at the end of the section.

The four strategies are:

- Strategy I - Continuation of Present Policies.
- Strategy II - Reprioritization of a Fixed Budget.
- Strategy III - Full Funding of Minimum System Needs.
- Strategy IV - Enhanced Navigation System Capability.

Some additional costs associated with Strategy IV are discussed under that topic.

STRATEGY I - CONTINUATION OF PRESENT POLICIES

The intent of Strategy I is to replicate, as closely as possible, the extension of present policies through the year 2003, constrained by a fixed annual budget for operations, maintenance, rehabilitation, and construction (after 1990 when the major construction costs for completing the present navigation system have been incurred). Execution of this strategy would include the completion of all navigation system projects currently under construction plus a fixed real budget in 1977 dollars of $585 million per year.

Under Strategy I, first priority would be given to the ongoing operations, maintenance, and rehabilitation of the entire existing navigation system. The real increase in dredging cost and the need for structural rehabilitation of existing facilities

would consume an increasing share of the total fixed budget at the expense of new construction and safety actions. Lock capacity expansion would be undertaken in Strategy I when lock utilization reaches 95% if funding were available after meeting all needs for operations, maintenance, and rehabilitation from the fixed budget. Actions to improve safety would be undertaken only if funding is available after meeting all other priorities. The Strategy I decision criteria are summarized in Exhibit XV.

Applying Strategy I to the present navigation system would result in the following needs being met.

1. The present system would be completed by about 1990.

2. The present system would continue to operate, channels would be maintained and needed lock rehabilitation would be undertaken through about 2000. Thereafter the total fixed budget would be inadequate for full funding and rehabilitation or dredging would likely be deferred.

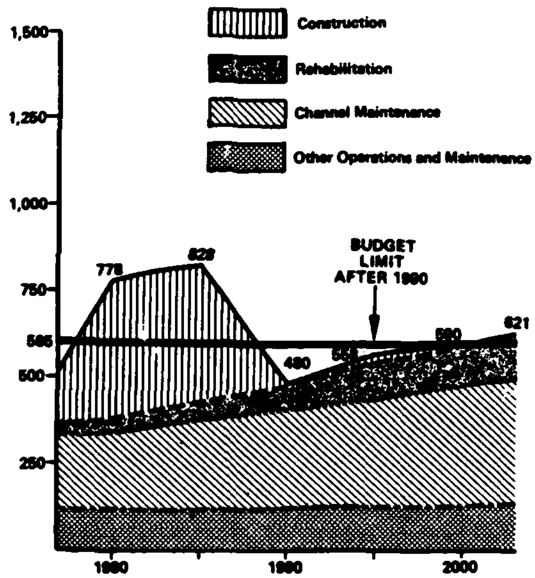
3. Only Lock and Dam 26 on the Mississippi River would receive funding for additional capacity construction from the Corps budget. Five locks on the Welland Canal would probably be expanded with funding from user tolls. Managerial actions at other locks would increase throughput, but congestion would increase substantially at Gallipolis, Uniontown, Demopolis, and perhaps the Inner Harbor lock.

No funds would be available for a program of safety improvements.

A summary of actions taken by scenario for Strategy I are shown in Exhibit XVI. Note that actions do not vary across scenarios. Total programmed expenditures under Strategy I are shown in Figure BB for the baseline scenario.

FIGURE 8B

PROJECTED COSTS OF STRATEGY I [1]
(MILLIONS OF 1977 DOLLARS)



Note: [1] Baseline scenario only.
Source: NWS, Evaluation of Alternative Future Strategies for Action, 1981.

Operations and maintenance of the existing system (other than dredging) remains relatively constant in 1977 dollars. Dredging consumes an increasing share of the annual budget due to the real rise in the cost of dredge disposal and energy. Rehabilitation of older lock structures also consumes an increasing share of the annual budget. Construction prior to 1990 is entirely for completion of the navigation system. The 1995 construction allocation is for a second 1,200-foot chamber at Lock and Dam 26.

Table 29 shows cumulative expenditures by scenario.

TABLE 29

STRATEGY I CUMULATIVE PUBLIC COSTS 1977-2003

	BILLIONS OF 1977 DOLLARS			
	Baseline	High Use	Low Use	Bad Energy
INLAND				
Construction	$3.3	$3.3	$3.3	$3.3
Rehabilitation	1.8	1.8	1.8	1.8
Channel Maintenance	1.9	1.9	1.9	1.9
Other O&M	2.7	2.7	2.7	2.7
Subtotal	9.7	9.7	9.7	9.7
GREAT LAKES				
Construction	0.0	0.0	0.0	0.0
Rehabilitation	0.1	0.1	0.1	0.1
Channel Maintenance	0.6	0.6	0.6	0.6
Other O&M	0.3	0.3	0.3	0.3
Subtotal	1.0	1.0	1.0	1.0
COASTS				
Construction	0.0	0.0	0.0	0.0
Rehabilitation	0.2	0.2	0.2	0.2
Channel Maintenance	4.9	4.9	4.9	4.9
Other O&M	0.6	0.6	0.6	0.6
Subtotal	5.7	5.7	5.7	5.7
TOTAL SYSTEM				
Construction	3.3	3.3	3.3	3.3
Rehabilitation	2.1	2.1	2.1	2.1
Channel Maintenance	7.4	7.4	7.4	7.4
Other O&M	3.6	3.6	3.6	3.6
TOTAL	$16.4	$16.4	$16.4	$16.4

Note that essentially all construction goes for the completion of the present system. Thus, the inland system receives the majority of total funds. Also, there is no difference among scenarios.

Under Strategy I, funding is not adequate to meet the minimum needs described in Section VII. Although Lock and Dam 26 is expanded, Gallipolis, Uniontown, and Demopolis, would not be replaced even though they represent primary constraints. No safety improvement actions would be funded and system maintenance would be adequate only for about the first 20 years of the time horizon.

STRATEGY II - REPRIORITIZATION OF A FIXED BUDGET

The intent of Strategy II is to reallocate a fixed annual budget to focus attention on the needs of the primary, high volume navigation system at the expense of low volume, high cost waterways branches and small ports.

To apply this strategy, shallow draft waterways were divided into three classes: A, B, and C, based upon the projected operations and maintenance cost per ton-mile of traffic in the year 2003. Further, costs associated with operating and maintaining side channels (short spurs which do not carry through traffic) were identified and separated. Finally, costs of operating and maintaining small ports, handling less than one million tons of cargo in 1977, were identified and isolated. The fixed budget was assumed to be identical to that of Strategy I.

Decision priorities for Strategy II were assumed to be as follows (see Exhibit XV for details):

1. Meet all operations, maintenance, rehabilitation, safety, and construction needs of all Class A shallow draft waterways, Great Lakes, and major ports, including capacity expansion actions at locks with 95% or more utilization and/or potential diversions of 1,000,000 tons or more of energy and grain commodities per year.

2. With remaining funds, meet all operations, maintenance, rehabilitation, safety, and construction needs of Class B shallow draft waterways using criteria as above.

3. With remaining funds, meet all operations, maintenance, rehabilitation, safety, and construction needs of Class C shallow draft waterways.

4. With remaining funds meet all operations, maintenance, rehabilitation, safety, and construction needs of side channels and minor ports.

Applying Strategy II to the present navigation system would result in the following needs being met.

1. The present system would be completed by about 1990.

2. All Class A and B shallow draft waterways, the Great Lakes/St. Lawrence Seaway System and major ocean ports would:

- Be fully operational and adequately maintained through the study time horizon of 2003.

- Receive full funding for needed rehabilitation of structures.

- Receive full funding for all safety improvement actions outlined in Exhibits XII and XIV.

3. All primary and secondary constraining locks would be expanded as needed under the baseline, high use, low use, and bad energy scenarios. Those becoming constrained under the hypothesized high coal export scenario would remain constraining. Managerial actions would be taken to increase throughput at all other congested locks.

4. Federal support would be withdrawn, however, from all minor ports, side channels, and Class C shallow draft waterways including:

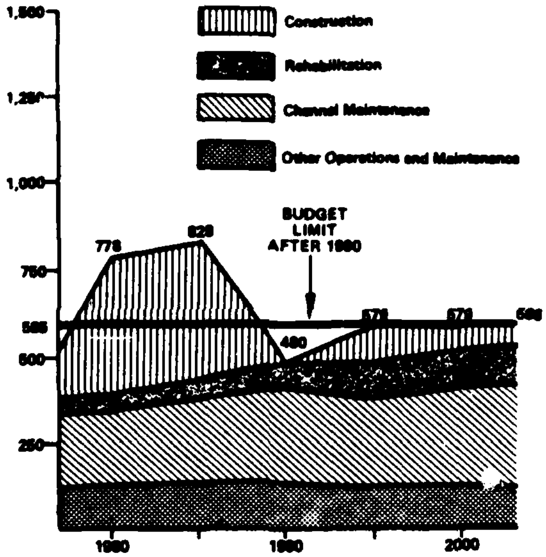
- Kentucky River.
- Alabama-Coosa system.
- Apalachicola-Chattahoochee-Flint system.
- Ouachita-Black-Red system.
- Old and Atchafalaya system.
- Atlantic Intracoastal Waterway between Miami and Norfolk.
- Arkansas River.

A summary of actions taken by scenario for Strategy II are shown in Exhibit XVII. Total programmed expenditures are shown in Figure CC for the baseline scenario.

FIGURE CC

PROJECTED COSTS OF STRATEGY II[1]

(MILLIONS OF 1977 DOLLLARS)



Note: [1]Baseline scenario only
Source: NWS, Evaluation of Alternative Future Strategies for Action, 1981.

Operations and maintenance, other than dredging, remain essentially flat in 1977 dollars through the 25-year time horizon. Maintenance dredging increases somewhat but not nearly as sharply as for Strategy I, because of the elimination of dredging on some high cost, low traffic rivers and smaller ports. Rehabilitation costs are essentially as in Strategy I. Construction, after completion of the current system in 1990, is focused on the expansion of the key constraining locks on the major waterways systems.

Cumulative public costs are shown in Table 30.

TABLE 30

STRATEGY II CUMULATIVE PUBLIC COSTS 1977-2003

	BILLIONS OF 1977 DOLLARS			
	Baseline	High Use	Low Use	Bad Energy
INLAND				
Construction	4.0	4.0	3.8	4.0
Rehabilitation	1.7	1.7	1.7	1.7
Channel Maintenance	1.7	1.7	1.9	1.8
Other O&M	2.7	2.6	2.7	2.6
Subtotal	10.1	10.0	10.1	10.1
GREAT LAKES				
Construction	0.0	0.0	0.0	0.0
Rehabilitation	0.1	0.1	0.1	0.1
Channel Maintenance	0.6	0.6	0.6	0.6
Other O&M	0.2	0.2	0.2	0.2
Subtotal	0.9	0.9	0.9	0.9
COASTS				
Construction	0.0	0.0	0.0	0.0
Rehabilitation	0.2	0.2	0.2	0.2
Channel Maintenance	4.6	4.6	4.6	4.6
Other O&M	0.6	0.6	0.6	0.6
Subtotal	5.4	5.4	5.4	5.4
TOTAL SYSTEM				
Construction	4.0	4.0	3.8	4.0
Rehabilitation	2.0	2.0	2.0	2.0
Channel Maintenance	6.9	6.9	7.1	7.0
Other O&M	3.5	3.4	3.5	3.4
Total	$16.4	$16.4	$16.4	$16.4

Completion of the present system continues to consume the vast majority of the construction budget thereby investing heavily in the inland system. Operation of inland system and ocean ports remain about equal. Again, there is little difference among scenarios.

Under Strategy II all of the minimum needs of the present system are met for all Class A and B shallow draft waterways, Great Lakes and major ports through the year 2003. Class C waterways, side channels and small ports, however, would not be funded at all.

STRATEGY III - FULL FUNDING OF MINIMUM SYSTEM NEEDS

The intent of this strategy would be to fully fund all operations, maintenance, safety actions, rehabilitation, and construction necessary for the maintenance of the present system in good order, including adequate lock capacity to handle projected traffic under all scenarios. Thus, this strategy calls for the completion of all actions identified in Strategy II without funding limitation.

Implementation of Strategy III would call for the following actions:

1. Completion of the present navigation system.

2. Construction of additional capacity (under all scenarios) at Lock and Dam 26, Welland Canal, Gallipolis, Demopolis, La Grange, Peoria, Marseilles, and Oliver Locks. Construction of additional capacity would be required under most scenarios for Lock and Dam 22 on the Mississippi River. Additional lock construction would be needed under some scenarios as shown in Exhibit XVIII. In addition, management actions to increase throughput at other congested locks would be taken.

3. Implementation of safety actions described in Exhibits XII and XIV.

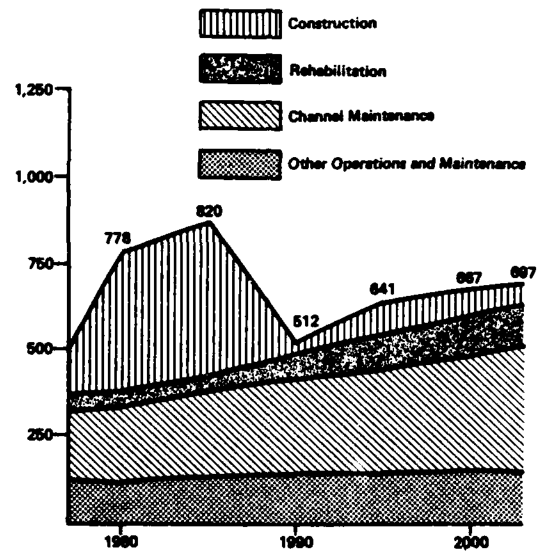
4. Provision of adequate funds for operations, maintenance, and rehabilitiation on all parts of the navigation system through the year 2003.

A summary of actions for Strategy III are shown in Exhibit XVIII. Figure DD displays the cost associated with implementing Strategy III under the baseline scenario.

FIGURE DD

PROJECTED COSTS OF STRATEGY III [1]

(MILLIONS OF 1977 DOLLARS)



Note: [1] Baseline scenario only.
Source: NWS, Evaluation of Alternative Future Strategies for Action, 1981.

Operations and maintenance, other than dredging, increases modestly (in real 1977 dollars) over the 25-year time frame from $126 million in 1977 to $148 million in 2003, as lock capacity is added requiring additional operations and maintenance. Dredging costs increase as in Strategy I. Rehabilitation is slightly less than in Strategy I as some locks are replaced rather than rehabilitated. Construction, after completion of the present system in 1990, includes the locks identified previously as well as safety actions. Total expenditures in 1990 are $512 million with increases to $641 million in 1995, $667 million in 2000, and $697 million in 2003.

Table 31 shows cumulative public costs associated with Strategy III.

TABLE 31

STRATEGY III CUMULATIVE PUBLIC COSTS 1977-2003

	BILLIONS OF 1977 DOLLARS					
	Baseline	High Use	Low Use	Bad Energy	High Coal Exports	Defense
INLAND						
Construction	4.2	4.6	4.1	4.4	4.9	4.8
Rehabilitation	1.8	1.8	1.8	1.8	1.8	1.8
Channel Maintenance	1.9	1.9	1.9	1.9	1.9	1.9
Other O&M	2.9	2.9	2.9	2.9	2.9	2.9
Subtotal	10.8	11.2	10.7	11.0	11.5	11.4
GREAT LAKES						
Construction	0.1	0.1	0.1	0.1	0.1	0.2
Rehabilitation	0.1	0.1	0.1	0.1	0.1	0.1
Channel Maintenance	0.6	0.6	0.6	0.6	0.6	0.6
Other O&M	0.3	0.3	0.3	0.3	0.3	0.3
Subtotal	1.1	1.1	1.1	1.1	1.1	1.2
COASTS						
Construction	0.0	0.1	0.0	0.0	0.1	0.1
Rehabilitation	0.2	0.2	0.2	0.2	0.2	0.2
Channel Maintenance	4.9	4.9	4.9	4.9	4.9	4.9
Other O&M	0.6	0.7	0.6	0.6	0.7	0.7
Subtotal	5.7	5.9	5.7	5.7	5.9	5.9
TOTAL SYSTEM						
Construction	4.3	4.8	4.2	4.5	5.1	5.1
Rehabilitation	2.1	2.1	2.1	2.1	2.1	2.1
Channel Maintenance	7.4	7.4	7.4	7.4	7.4	7.4
Other O&M	3.8	3.9	3.8	3.8	3.9	3.9
Total	$17.6	$18.2	$17.5	$17.8	$18.5	$18.5

Total expenditures range from $17.5 billion under the low use scenario to $18.5 billion under high coal exports, showing the lack of sensitivity to traffic levels of meeting the minimum system needs.

Strategy III meets all minimum navigation system needs at a cost of $1.1 billion to $2.1 billion more than Strategies I or II over the 25-year time horizon. This represents a difference in real budget levels of from 6.7% to 12.8% over the present levels assumed in Strategies I and II.

STRATEGY IV -
ENHANCED NAVIGATION
SYSTEM CAPABILITY

The intent of this strategy would be to implement all logical improvements to the waterways system to increase its capability, without extending it geographically.

Under Strategy IV, the following investments would be made:

1. Completion of the Present System. Same as in previous three strategies. Total cost $3,070,647,000 in 1977 dollars.

2. Operations and Normal Maintenance. All normal operations and maintenance activities (other than dredging, discussed below) would be carried out for the existing navigation system. The cost of this is estimated to increase from $126 million in 1977 to $135 million in 1977 dollars in the year 2003, due to the opening of waterways currently under construction.

3. Maintenance Dredging of Channels. Necessary dredging on all shallow draft waterways, Great Lakes, and coastal ports including minor ports and side channels would be undertaken. This is estimated to increase in cost from $206 million in 1977 to $360 million, in 1977 dollars, in 2003.

4. Rehabilitation. All necessary structural rehabilitation of locks and other navigation structures would be carried out in a timely manner. Note that some rehabilitation called for under Strategies II and III is unnecessary under Strategy IV, since the additional construction activity (Discussed below) eliminates the need for some rehabilitation. The total cost of rehabilitation under Strategy IV is estimated to increase from $37 million in 1977 to $105 million, in 1977 dollars, in 2003.

5. Structural Actions to Increase Lock Capacity. All constraining or congested locks would be expanded when their utilization reaches 85% of practical lock capacity.

6. Inexpensive Safety Actions. Implementation of all identified nonstructural and minor structural safety enhancements, at all identified high-risk sections of the navigation system as shown in Exhibits XII and XIV would be programmed. The cost of this program in 1977 dollars is estimated to be $281 million plus $18 million per year in increased operating costs.

7. Port Deepening. Five ocean ports would be deepened by 1990 under Strategy IV to 50-55 feet via dredging. These include Baltimore, Hampton Roads, Mobile, New Orleans/Baton Rouge, and Galveston. Total estimated construction costs for this port deepening is estimated to be $1,150 million in 1977 dollars. Increased annual dredging costs are estimated to be $30 million based on data supplied by the Corps.

8. Replacing Obsolete Locks. Eleven locks were considered to be obsolete, yet important to the navigation system. Modification or replacement of locks with modern facilities under Strategy IV would enhance navigation, and reduce future rehabilitation costs. The following locks fall into this category:

- Lock and Dam No. 1 on the Upper Mississippi River near Minneapolis.
- Lock and Dams 3, 4, 7, and 8 on the Monongahela.
- Winfield and Marmet Locks on the Kanawha.
- Harvey Lock on the Gulf Intracoastal Waterway west of New Orleans.
- Inner Harbor Lock on the Gulf Intracoastal Waterway east of New Orleans.
- Oliver Lock on the Warrior system.
- Bonneville Lock on the Columbia River.

Total estimated construction costs for these lock replacements is $713 million. Ongoing operations and maintenance costs are, however, no higher.

9. Deepening Shallow Draft Waterways. Four waterways have been identified as candidates for deepening to increase the carrying capacity of barges and thus enhance the capability of the system. One waterway has been identified as a candidate for widening with the same objective. These five waterways are:

- Deepening of the Ohio River from Pittsburgh to its confluence with the Mississippi at Cairo, Illinois to 12 feet, requiring increased dredging and the addition of five lock chambers with deeper sills. Estimated construction cost for this channel deepening action, including lock replacement, is $625 million.

- Deepening of the Illinois Waterway from Chicago to its confluence with the Mississippi to 12 feet, requiring dredging and replacement of all seven lock chambers to accommodate greater depth. Estimated construction cost is $716 million dollars plus $3 million per year in increased dredging maintenance costs.

- Deepening of the Upper Mississippi River from Dubuque, Iowa to the mouth of the Illinois River to 10 feet requiring increased dredging and replacement of six lock chambers to accommodate greater depth. Estimated construction cost is $300 million plus $100 million per year in increased dredging costs.

- Deepening of the Mississippi River from the mouth of the Illinois to Cairo to 12 feet, requiring additional dredging. Estimated construction cost is $283 million plus $8 million per year in additional dredging maintenance.

- Widening of the Tombigbee River from Demopolis to Mobile to accommodate an eight-barge tow. Estimated construction cost is $90 million.

10. Major Safety Improvements. In addition to the relatively inexpensive safety improvements identified above, 21 major structural actions, including bridge removals, alterations and replacements as well as rock cuts at narrow spots, would be made under Strategy IV. Exhibit XIX lists these actions and associated costs by region. Estimated additional construction costs beyond those above is $262 million.

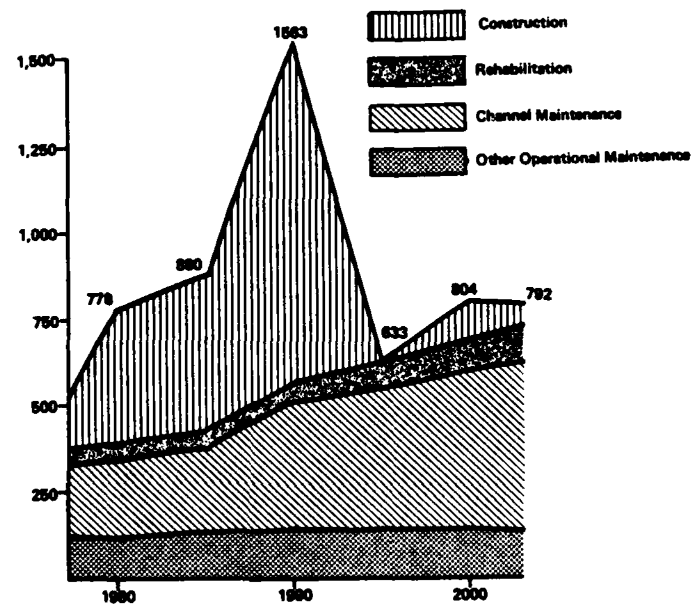
11. Deferred Maintenance Dredging. Over the years, the Corps of Engineers has deferred some maintenance dredging for a variety of reasons. Under Strategy IV, this could be resumed to improve channel reliability. Total estimated cost is $30 million per year in 1977 dollars, plus real cost increases. Exhibit XX shows all actions programmed under Strategy IV.

The total cost of implementing all actions identified above for Strategy IV under the baseline scenario is shown in Figure EE, assuming major construction actions are taken in the 1990 time frame.

FIGURE EE

PROJECTED COSTS OF STRATEGY IV[1]

(MILLIONS OF 1977 DOLLARS)



Note: [1] Baseline scenario only.
Source: NWS, Evaluat · of Alternative Future Strategies for Action, 1981.

Note that operations and maintenance (other than dredging) are relatively flat, reflecting only the increased operating costs of new construction. Maintenance dredging increases rapidly as the port and channel deepening actions are taken. This expenditure also increases with the inclusion of deferred maintenance dredging program. Rehabilitation costs are actually slightly less than in earlier strategies, because many older facilities are replaced instead of being rehabilitated. Construction costs skyrocket as the current system is completed, and as the major construction projects are undertaken to improve the navigation system. Note that construction for capacity lock replacement in the later

years is more modest than in Strategy III, since channel deepening allows existing locks to pass greater tonnages of cargo. Also, some locks that would be replaced for capacity reasons in Strategy III would be replaced sooner as a part of the deepening or obsolescence programs under Strategy IV.

Total expenditures for the entire Strategy IV program, implemented on an aggressive time schedule, peak at $1,563 million per year in 1990.

Table 32 shows cumulative public expenditures for Strategy IV.

TABLE 32

STRATEGY IV CUMULATIVE PUBLIC COSTS 1977-2003

	BILLIONS OF 1977 DOLLARS					
	Baseline	High Use	Low Use	Bad Energy	High Coal Exports	Defense
INLAND						
Construction	6.5	8.4	6.4	7.7	8.6	7.3
Rehabilitation	1.6	1.5	1.5	1.5	1.5	1.5
Channel Maintenance	2.2	2.3	2.3	2.3	2.3	2.3
Other O&M	2.9	2.9	2.9	2.9	2.9	2.9
Subtotal	13.2	15.1	13.1	14.4	15.3	14.0
GREAT LAKES						
Construction	0.2	0.2	0.1	0.2	0.2	0.2
Rehabilitation	0.1	0.1	0.1	0.1	0.1	0.1
Channel Maintenance	0.7	0.7	0.7	0.7	0.7	0.7
Other O&M	0.3	0.3	0.3	0.3	0.3	0.3
Subtotal	1.3	1.3	1.2	1.3	1.3	1.3
COASTS						
Construction	1.0	1.1	1.0	1.1	1.1	1.0
Rehabilitation	0.2	0.2	0.2	0.2	0.2	0.2
Channel Maintenance	6.1	6.1	6.1	6.1	6.1	6.1
Other O&M	0.7	0.7	0.7	0.7	0.7	0.7
Subtotal	8.0	8.1	8.0	8.1	8.1	8.0
TOTAL SYSTEM						
Construction	7.7	9.7	7.5	9.0	9.9	8.5
Rehabilitation	1.9	1.8	1.8	1.8	1.8	1.8
Channel Maintenance	9.0	9.1	9.1	9.1	9.1	9.1
Other O&M	3.9	3.9	3.9	3.9	3.9	3.9
Total	$22.5	$24.5	$22.3	$23.8	$24.7	$23.3

Due to completion of the existing system and major enhancements, the vast majority of construction funding would go to the inland system under Strategy IV. Total expenditures range from $20.5 billion under baseline scenario to $24.7 billion under high coal exports.

Total expenditures for enhancing the navigation system range from $4.1 billion (25%) to $8.3 billion (50%) more than present real funding levels, depending on scenario.

COMPARISON OF STRATEGIES

Figure FF below shows the estimated cost of implementing each of the alternative strategies over the 25-year time horizon of this study.

FIGURE FF

PROJECTED COSTS OF STRATEGIES I, II, III, and IV (1)

(MILLIONS OF 1977 DOLLARS)

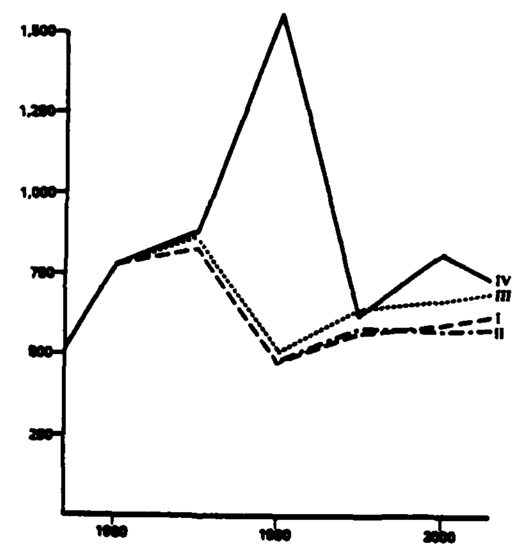


Table 33 on the next page shows the breakdown of expenditures by area of the navigation system for the baseline scenario.

TABLE 33

CUMULATIVE PROJECTED EXPENDITURES FOR BASELINE SCENARIO UNDER FOUR POSSIBLE STRATEGIES 1977-2003 (1)

AREA	BILLIONS OF 1977 DOLLARS STRATEGY I	II	III	IV
INLAND	$ 9.7	$10.2	$10.8	$13.3
GREAT LAKES/SEAWAY	1.0	0.9	1.1	1.2
COASTAL	5.7	5.3	5.7	8.0
TOTAL	$16.4	$16.4	$17.6	$22.5

Note: (1)Includes estimated Corps of Engineers' expenditures and cost of additional safety actions which would be incurred by Corps and Coast Guard. Does not include ongoing Coast Guard expenditures, Caribbean or St. Lawrence Seaway Development costs nor state, local or private expenditures.

Source: NWS, Evaluation of Alternative Strategies for Action.

Implementation of Strategy I would cost about $16.4 billion over the 25-year time frame with $9.7 billion going to the shallow draft inland waterways, $1.0 billion for the Great Lakes/ St. Lawrence Seaway (not including direct expenditures by the Seaway Development Corporation and Canadian authorities), and $5.7 billion for coastal ports and deep draft channels.

Strategy II reallocates the same $16.4 billion adding about $0.5 billion to the expenditures for the shallow draft waterways and subtracting $0.5 billion from coastal and Great Lakes expenditures, reflecting a withdrawal of support for minor ports and a reallocation of expenditures to ports and waterways that carry the overwhelming majority of traffic.

Strategy III reflects the full funding of all needed actions to effectively maintain and operate the present waterway system, including removal of all capacity constraints. It costs approximately $1.6 billion more than Strategy II.

Strategy IV enhances the present navigation system at a cost of an additional $4.9 billion.

Adequate capacity to handle all of the projected waterborne traffic through 2003 is provided under Strategies III and IV. Improvement of navigation safety through the mitigation of hazards at approximately 200 key points in the navigation system is provided under Strategies II, III and IV. The competitiveness of the marine mode is maintained on main channels and at major ports in Strategies II and III. Modal competitiveness is enhanced in Strategy IV through actions to deepen the system and improve its reliability.

Table 34 displays cumulative expenditures for each scenario/strategy combination for reference.

TABLE 34

CUMULATIVE EXPENDITURES FOR ALL STRATEGIES/SCENARIO COMBINATIONS 1977-2003

	BILLIONS OF DOLLARS					
STRATEGY	BASELINE	HIGH USE	LOW USE	BAD ENERGY	HIGH COAL EXPORTS	DEFENSE
I	16.4	16.4	16.4	16.4	*	*
II	16.4	16.3	16.4	16.4	*	*
III	17.6	18.2	17.5	17.8	18.5	18.5
IV	22.5	24.5	22.3	23.8	24.7	23.3

* not evaluated.

IMPACTS OF ALTERNATIVE STRATEGIES

Table 35 on the next page shows the impact of each strategy on the projected linehaul cost of water carriers in the year 2003.

TABLE 35

SAVINGS IN LINEHAUL COSTS FOR DOMESTIC INLAND WATERWAYS AND GREAT LAKES TRAFFIC IN 2003 FOR THE BASELINE SCENARIO (1)

REGION	(MILLIONS OF 1977 DOLLARS) STRATEGY I	II	III	IV
UPPER MISSISSIPPI	$ 2	$11	$11	$29
LOWER UPPER MISSISSIPPI	57	57	57	94
LOWER MISSISSIPPI	-	-	13	142(2)
BATON ROUGE TO GULF	4	11	(4)	42(2)
ILLINOIS WATERWAY	-	14	13	40
MISSOURI RIVER	-	(1)	(1)	(1)
OHIO	(9)	-	-	115
TENNESSEE RIVER	-	1	4	4
GULF COAST WEST(2)	-	-	25	55
GULF COAST EAST	0	1	1	4
MOBILE RIVER AND TRIBUTARIES	-	13	15	34
GREAT LAKES/SEAWAY	-	-	-	13
TOTAL	$54	$107	$134	$571

Notes: (1)Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present waterways system and the modified system under each of the four strategies.
(2)Savings are due to system interactions with those upstream channels that would be deepened and that in 1990 would permit the same depth of loaded barges as these three regions where no direct action would be taken.

Source: NWS, Evaluation of Alternative Future Strategies for Action, 1981.

The expansion of capacity at Lock and Dam 26 alone results in an annual savings in 2003 (in 1977 dollars) of $57 million over the cost that would be incurred without that capacity expansion. The reallocation of resources in Strategy II to focus on the high-volume waterways results in a further reduction in linehaul costs of $53 million per year for a total of $107 million.

Strategy III, which fully funds the proper management of the present navigation system, results in a further savings of $27 million for a total of $134 million per year. Enhancement of the present system in Strategy IV results in a dramatic reduction of an additional $437 million per year for a total savings of $571 million per year in linehaul costs over the present system.

It should be noted that there are additional significant savings in transportation costs for foreign trade under Strategy IV as a result of port deepening. These have not been estimated.

In addition to the reduced linehaul costs, most of the traffic not accommodated by the present system without capacity expansion could be accommodated. If no actions at all were taken under the baseline scenario, approximately 36 million tons of potential waterborne traffic would not be accommodated (see Table 22). Under Strategy I, 24 of the 36 million tons would be accommodated. Under Strategies II, III, and IV, all 36 million tons would be accommodated. In the case of Strategy II, however, this tonnage is accommodated at the expense of traffic on high-cost waterways.

Implementation of an extensive program of safety improvements, under Strategies II, III, and IV, should result in additional (but unquantified) savings through fewer accidents and fewer cargo spills. Thus, the safety improvement program would also tend to have positive environmental impacts as well.

Because of the historic pass-through of the increases or decreases in cost by the free-market pricing of water transportation services, **the alternative strategies are expected to have little overall impact on the financial viability of water carriers.** A high percentage of savings or additional expenses would tend to be passed through directly to shippers.

Throughout the development of the forecast and the analysis of this study, the assumption has been made that there is continuing parity between the competitive modes of transportation and that no one mode will acquire a significant cost advantage or disadvantage vis-a-vis historical relationships. Thus, the traffic which is forecasted as potential for the waterways is that traffic which would "normally" go by water if sufficient capacity were available. As a result, **the implementation of Strategies I, II, or III would not have a significant impact on other modes of transportation since it would not alter the modal competitive relationships. Strategy IV, however, would tend to decrease the cost of water transportation and, therefore, might increase the market share of the water mode.**

Generally, there is little interaction between the uses of water for navigation and the uses for other purposes. **Therefore, there is little impact on other waterway users between strategies.**

However, Strategies III and IV tend to be more supportive of fishermen, recreational boaters, and offshore supply industries because of the maintenance of smaller harbors and because sufficient lock capacity would be available to accommodate all traffic (including these users).

Environmental impacts do not vary significantly among Strategies I through III. In none of these are any new dams constructed (except for completion of the present system). Dredging costs in all cases reflect acceptable practices for dredged material disposal and safety actions tend to reduce the incidence of accidents and cargo spills. Strategies II and III are slightly better than Strategy I since safety actions are included which reduce the incidence of accidents and, therefore, hazardous cargo spills.

Strategy IV calls for deepening of a number of rivers and harbors by means of dredging. However, the cost scheduled for these actions reflect the proper disposal of all dredged material. **The negative environmental impact that is clearly apparent is the potential for resuspension of polluted industrial waste from harbor bottoms during the dredging process in some local circumstances.**

SUMMARY

Table 36 on the next page displays a comparison of the four strategies (under the baseline scenario for reference) on key measures of effectiveness.

TABLE 36

SUMMARY COMPARISON OF STRATEGIES UNDER BASELINE SCENARIO

	STRATEGY I	II	III	IV
FUNDING OF OPERATIONS AND MAINTENANCE THROUGH 2003?	NO	YES	YES	YES
FUNDING OF REHABILITATION THROUGH 2003?	NO	YES	YES	YES
NUMBER OF LOCK ACTIONS ASSUMED TO BE IMPLEMENTED:				
EXPANSION OF CAPACITY	6	11	13	12
OBSOLETE LOCK REPLACEMENT	0	0	0	10
CHANNEL DEEPENING	0	0	0	18
NUMBER OF SAFETY ACTIONS ASSUMED TO BE IMPLEMENTED:				
MINOR AND NONSTRUCTURAL ACTIONS	0	188	191	200
MAJOR STRUCTURAL ACTIONS	0	0	0	21
PORT DEEPENING ACTIONS	0	0	0	5
CHANNEL DEEPENING ACTIONS	0	0	0	4
CHANNEL WIDENING ACTION	0	0	0	1
FUNDING OF ANNUAL DEFERRED MAINTENANCE DREDGING?	NO	NO	NO	YES
MILLIONS OF TONS NOT ACCOMMODATED IN 2003	11	18(1)	0	0
AVERAGE DOMESTIC LINEHAUL COST (MILLS PER TON-MILE 2003)	7.8	7.7	7.8	7.1
CUMULATIVE PUBLIC EXPENDITURES (BILLIONS OF 1977 DOLLARS - 1977 TO 2003)	$16.4	$16.4	$17.6	$22.5
ANNUAL REDUCTION IN DOMESTIC LINEHAUL COSTS (MILLIONS OF 1977 DOLLARS IN 2003)	$57	$107	$134	$571

Note: (1) Includes traffic not accommodated on Class C segments due to the assumed withdrawal of federal support by 2003.

Source: NWS, Evaluation of Alternative Future Strategies for Action, 1981.

The overall conclusions that can be drawn from an examination of the four hypothetical strategies are as follows:

- Strategy I, by continuing present practices under a fixed real budget, performs moderately well to the year 2000 but will result in major deterioration of the main line navigation system and major ports after the turn of the century.

- Strategy II, by focusing resources on the main line navigation system and major ports, will tend to perform much better after the turn of the century than Strategy I, given the same fixed real budget constraint.

- Strategy III allows the continuation of support for minor rivers, side channels, and minor ports, at a cost of approximately $1.0 billion. The addition of desirable (but not critical) incremental lock capacity on major rivers under this Strategy costs an additional $0.2 billion.

- Strategy IV enhances the capacity, competitiveness, and reliability of the nation's water transportation system at an additional cost of approximately $4.9 billion over the next 25 years and results in an additional annual savings in operating cost of $419 million per year over Strategy III for domestic marine carriers. This strategy also enhances the competitiveness of U.S. exports in world markets via deeper harbors to accommodate more efficient oceangoing vessels.

NATIONAL WATERWAYS STUDY

NWS REGIONS AND ANALYTICAL SEGMENTS

NWS REPORTING REGION	DESCRIPTION	ANALYTICAL SEGMENT
I. UPPER MISSISSIPPI RIVER	MINNEAPOLIS, MN TO MOUTH OF ILLINOIS RIVER	1. UPPER MISSISSIPPI
II. LOWER UPPER MISSISSIPPI RIVER	MOUTH OF ILLINOIS RIVER TO MOUTH OF OHIO RIVER AT CAIRO, IL	2. LOWER UPPER MISSISSIPPI RIVER (ILLINOIS RIVER TO MISSOURI RIVER)
		3. MIDDLE MISSISSIPPI RIVER (MISSOURI RIVER TO OHIO RIVER INCLUDING KASKASKIA RIVER)
III. LOWER MISSISSIPPI RIVER CAIRO TO BATON ROUGE	MOUTH OF OHIO RIVER (CAIRO, IL) TO BATON ROUGE, LA	4. LOWER MIDDLE MISSISSIPPI RIVER (OHIO RIVER TO WHITE RIVER)
		5. UPPER LOWER MISSISSIPPI RIVER (WHITE RIVER TO OLD RIVER)
		6. LOWER MISSISSIPPI RIVER - OLD RIVER TO BATON ROUGE
IV. LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	BATON ROUGE, LA (INCLUDING PORT) TO MOUTH OF PASSES AND OTHER CHANNELS AND RIVERS	7. MISSISSIPPI RIVER - BATON ROUGE TO NEW ORLEANS
		8. MISSISSIPPI RIVER - NEW ORLEANS TO GULF
		25. OUACHITA - BLACK AND RED RIVERS
		26. OLD AND ATCHAFALAYA RIVERS
		27. BATON ROUGE TO MORGAN CITY, LOUISIANA BYPASS
V. ILLINOIS WATERWAY	CHICAGO, IL (GUARD LOCK AND T.J. O'BRIEN LOCK) TO MOUTH OF ILLINOIS RIVER	9. ILLINOIS WATERWAY
VI. MISSOURI RIVER	SIOUX CITY, IA TO MOUTH OF MISSISSIPPI RIVER	10. MISSOURI RIVER
VII. OHIO RIVER	HEADS OF NAVIGATION TO MOUTH	11. UPPER OHIO RIVER (CONFLUENCE OF MONONGAHELA AND ALLEGHENY AT PITTSBURGH, PA TO KANAWHA RIVER)
		12. MIDDLE OHIO RIVER (KANAWHA RIVER TO KENTUCKY RIVER)
		13. LOWER OHIO RIVER - THREE (KENTUCKY RIVER TO GREEN RIVER)
		14. LOWER OHIO RIVER - TWO (GREEN RIVER TO TENNESSEE RIVER)
		15. LOWER OHIO RIVER - ONE (TENNESSEE RIVER TO MOUTH)
		16. MONONGAHELA RIVER
		17. ALLEGHENY RIVER
		18. KANAWHA RIVER
		19. KENTUCKY RIVER
		20. GREEN RIVER AND BARREN RIVER
		21. CUMBERLAND RIVER

NATIONAL WATERWAYS STUDY

NWS REGIONS AND ANALYTICAL SEGMENTS (CONT'D)

NWS REPORTING REGION		DESCRIPTION	ANALYTICAL SEGMENT	
VIII.	TENNESSEE RIVER	HEAD OF NAVIGATION ABOVE KNOXVILLE, TN TO MOUTH	22.	UPPER TENNESSEE RIVER AND CLINCH RIVER (HEAD OF NAVIGATION TO JUNCTION WITH TENNESSEE-TOMBIGBEE WATERWAY)
			23.	LOWER TENNESSEE RIVER (FROM JUNCTION WITH TENNESSEE-TOMBIGBEE WATERWAY TO OHIO RIVER)
IX.	ARKANSAS RIVER	CATOOSA, OK (NEAR TULSA, OK) TO MOUTH	24.	ARKANSAS RIVER (INCLUDING VERDIGRIS, WHITE AND BLACK RIVERS)
X.	GULF COAST WEST	NEW ORLEANS TO BROWNSVILLE, TX	28.	GIWW WEST ONE (FROM NEW ORLEANS, LA TO CALCASIEU RIVER)
			29.	GIWW WEST TWO (CALCASIEU RIVER TO CORPUS CHRISTI, TX)
			30.	GIWW WEST THREE (CORPUS CHRISTI TO BROWNSVILLE)
			34.	HOUSTON SHIP CHANNEL
XI.	GULF COAST EAST	NEW ORLEANS TO KEY WEST, FL	31.	GIWW EAST ONE (NEW ORLEANS TO MOBILE BAY INCLUDING MISSISSIPPI RIVER GULF OUTLET AND PEARL RIVER)
			32.	GIWW EAST TWO (MOBILE BAY TO ST. MARKS, FL)
			33.	FLORIDA GULF COAST (ST. MARKS, FL TO KEY WEST, FL)
			38.	APALACHICOLA, CHATTAHOOCHEE, FLINT RIVERS
XII.	MOBILE AND TRIBUTARIES	HEAD OF NAVIGATION TO MOUTH	35.	BLACK WARRIOR MOBILE HARBOR (BLACK WARRIOR RIVER - HEAD OF NAVIGATION TO MOUTH, TOMBIGBEE RIVER - MOUTH OF BLACK WARRIOR RIVER TO CONFLUENCE WITH ALABAMA RIVER, MOBILE RIVER TO MOBILE BAY, MOBILE HARBOR)
			36.	ALABAMA-COOSA RIVERS
			37.	TENNESSEE-TOMBIGBEE WATERWAY
XIII.	SOUTH ATLANTIC COAST	KEY WEST, FL TO NORTH CAROLINA/VIRGINIA BORDER	39.	FLORIDA/GEORGIA COAST
			40.	CAROLINAS COAST

NATIONAL WATERWAYS STUDY

NWS REGIONS AND ANALYTICAL SEGMENTS (CONT'D.)

NWS REPORTING REGION	DESCRIPTION	ANALYTICAL SEGMENT(1)
XIV. MIDDLE ATLANTIC COAST	NORTH CAROLINA/VIRGINIA BORDER TO NEW YORK/CONNECTICUT BORDER	41. CHESAPEAKE AND DELAWARE BAYS
		42. NEW JERSEY/NEW YORK COASTS
XV. NORTH ATLANTIC COAST	HUDSON RIVER: FROM WATERFORD NY TO MOUTH; NEW YORK/CONNECTICUT BORDER TO CANADA BORDER	44. NORTH ATLANTIC COAST
XVI. GREAT LAKES/ST. LAWRENCE SEAWAY/ NEW YORK WATERWAYS		43. NEW YORK STATE WATERWAYS
		45. LAKE ONTARIO AND ST. LAWRENCE SEAWAY
		46. LAKE ERIE
		47. LAKE HURON
		48. LAKE MICHIGAN
		49. LAKE SUPERIOR
XVII. WASHINGTON/OREGON COAST	PUGET SOUND TO CALIFORNIA-OREGON BORDER	50. PUGET SOUND
		53. OREGON/WASHINGTON COAST
XVIII. COLUMBIA-SNAKE WATERWAY/WILLAMETTE RIVER	LEWISTON, ID TO MOUTH	51. UPPER COLUMBIA-SNAKE WATERWAY (LEWISTON, ID DAM TO BONNEVILLE LOCK AND DAM)
		52. LOWER COLUMBIA-SNAKE WATERWAY/ WILLAMETTE RIVER
XIX. CALIFORNIA COAST	CALIFORNIA-OREGON BORDER TO MEXICO-BORDER	54. NORTHERN CALIFORNIA (OREGON-CALIFORNIA BORDER TO SAN FRANCISCO BAY)
		55. SAN FRANCISCO BAY AREA, SACRAMENTO RIVER, AND SAN JOAQUIN RIVER
		56. CENTRAL/SOUTH CALIFORNIA (FROM SAN FRANCISCO BAY TO MEXICO BORDER)
XX. ALASKA		57. SOUTHEAST ALASKA (PANHANDLE)
		58. SOUTH CENTRAL ALASKA COAST
		59. WEST AND NORTH COASTS OF ALASKA (INCLUDING ALEUTIANS)
XXI. HAWAII AND PACIFIC TERRITORIES		60. HAWAII AND PACIFIC TERRITORIES
XXII. CARIBBEAN, INCLUDING PUERTO RICO AND VIRGIN ISLANDS		61. CARIBBEAN, INCLUDING PUERTO RICO AND VIRGIN ISLANDS

Note: (1) Rest of world not evaluated as part of the National Waterways Study.

Source: NWS, Evaluation of the Present Navigation System, 1981.

EXHIBIT II

NATIONAL WATERWAYS STUDY

NWS REPORTING AND ANALYTICAL COMMODITY GROUPS

AGGREGATE COMMODITY NAME	DETAILED COMMODITY NAME
I. FARM PRODUCTS	1. CORN 2. WHEAT 3. SOYBEANS 4. OTHER FARM PRODUCTS
II. METALLIC ORES	5. IRON ORE AND CONCENTRATES 6. OTHER ORES (INCLUDING BAUXITE)
III. COAL	7. COAL AND LIGNITE
IV. CRUDE PETROLEUM	8. CRUDE PETROLEUM
V. NONMETALLIC MINERALS	9. SAND, GRAVEL, AND CRUSHED ROCK 10. LIMESTONE 11. PHOSPHATE ROCK AND OTHER FERTILIZERS 12. SULFUR 13. OTHER NONMETALLIC MINERALS
VI. FOOD AND KINDRED PRODUCTS	14. VEGETABLE OILS 15. GRAIN MILL PRODUCTS 16. OTHER FOOD PRODUCTS
VII. LUMBER AND WOOD PRODUCTS	17. LOGS (INCLUDING PULPWOOD) 18. RAFTED LOGS 19. LUMBER AND PLYWOOD 20. OTHER LUMBER AND WOOD PRODUCTS
VIII. PULP, PAPER AND ALLIED PRODUCTS	21. PULP 22. OTHER PULP AND PAPER PRODUCTS
IX. CHEMICALS	23. SODIUM HYDROXIDE 24. CRUDE TAR, OIL AND GAS PRODUCTS 25. ALCOHOLS 26. BENZENE AND TOLUENE 27. SULPHURIC ACID 28. OTHER CHEMICALS 29. NITROGENOUS CHEMICAL FERTILIZERS 30. POTASSIC CHEMICAL FERTILIZERS 31. PHOSPHATIC CHEMICAL FERTILIZERS 32. OTHER FERTILIZER PRODUCTS
X. PETROLEUM AND COAL PRODUCTS	33. GASOLINE 34. JET FUEL AND KEROSENE 35. DISTILLATE 36. RESIDUAL 37. OTHER PETROLEUM AND COAL PRODUCTS, NEC
XI. STONE, CLAY, GLASS AND CONCRETE PRODUCTS	38. CEMENT 39. OTHER STONE, CLAY, GLASS PRODUCTS
XII. PRIMARY METALS PRODUCTS	40. COKE 41. IRON AND STEEL PRIMARY FORMS 42. STEEL MILL PRODUCTS (INCLUDING SHAPES, PLATES, PIPE AND TUBE) 43. PRIMARY METALS
XIII. WASTE AND SCRAP	44. METAL SCRAP 45. OTHER SCRAP
XIV. OTHER COMMODITIES	46. MARINE SHELLS 47. MISCELLANEOUS (INCLUDING FOREST PRODUCTS NOT ELSEWHERE CLASSIFIED, FISH, ORDNANCE, TOBACCO, TEXTILES, FURNITURE, PRINTED MATTER, RUBBER PRODUCTS, LEATHER, FABRICATED METAL, MACHINERY, TRANSPORTATION EQUIPMENT, INSTRUMENTS, OPTICAL GOODS, MISCELLANEOUS MANUFACTURERS, WATER, COMMODITY, NEC, LCL FREIGHT, AND DEPARTMENT OF DEFENSE CARGO) 48. WATERWAY IMPROVEMENT MATERIALS

Source: NWS, Workplan, 1979.

EXHIBIT III

THE NATIONAL WATERWAYS STUDY

PRINCIPAL ASSUMPTIONS FOR NWS SCENARIOS

PRINCIPAL ASSUMPTIONS	BASELINE	HIGH USE(1)	LOW USE	BAD ENERGY	DEFENSE	HIGH COAL EXPORTS
1. MACROECONOMIC	TRENDLONG	TRENDLONG	LARGER GOVERNMENT	BAD ENERGY	WARTIME ECONOMY(2)	TRENDLONG
2. CORN YIELDS BY 2003 (BUSHELS PER ACRE)	121	121	110	121	121	121
3. WEST COAST SHARE OF FARM PRODUCTS EXPORTS	14%	14%	14%(3)	14%	OVERALL DECLINE DURING CONFLICT	14%
4. PHOSPHATE EXPORTS	DECREASE AFTER 1985	CONSTANT AFTER 1985	DECREASE AFTER 1985	DECREASE AFTER 1985	CONSTANT AFTER 1985	CONSTANT AFTER 1985
5. STEEL IMPORTS (PERCENT OF TOTAL CONSUMPTION)	DECREASE AFTER 1990 FROM 17% TO 15%	DECREASE AFTER 1990 FROM 17% TO 15%	INCREASE TO 26% BY 2003	DECREASE AFTER 1990 FROM 17% TO 15%	DECLINE SHARPLY DURING CONFLICT	DECREASE AFTER 1990 FROM 17% TO 15%
6. CRUDE OIL PRICES (AVERAGE ANNUAL PRICE INCREASE)	3.8%	3.8%	3.8%	4.8%	3.8%	3.8%
7. CRUDE OIL IMPORTS BY 2003 (MILLIONS OF TONS)	290	290	240	200	DECLINE OF 100 MILLION TONS PER YEAR DURING CONFLICT	290
8. COAL EXPORTS BY 2003(4) (MILLIONS OF TONS)	107	156	107	156	156	290(5)
9. GULF COAST SHARE OF TOTAL COAL EXPORTS IN 2003(4) (PERCENT)	19%	23%	11%	23%	23%	35%
10. DOMESTIC COAL CONSUMPTION BY 2003 (MILLIONS OF TONS)	1,794	2,360	1,625	1,728	2,360	2,360
11. SYNFUEL PLANTS ON WATER (COAL CONSUMPTION IN MILLIONS OF TONS BY 2003)	10 (50)(6)	11 (61)	6 (30)(6)	15 (81)	11 (61)	11 (61)
12. COAL SLURRY PIPELINES	NONE	NONE	NONE	7 (7)	NONE	NONE
13. EASTERN COAL USE (LAKE ERIE LOADINGS OF COAL BY 2003 IN MILLIONS OF TONS)	PRESENT TECHNOLOGY AND REGULATIONS (20)	PRESENT TECHNOLOGY AND REGULATIONS (22)	INCREASED USE IN GREAT LAKES AREA (24)	PRESENT TECHNOLOGY AND REGULATIONS (20)	PRESENT TECHNOLOGY AND REGULATIONS (20)	PRESENT TECHNOLOGY AND REGULATIONS (20)

Notes: (1) A seventh "miscellaneous" sensitivities forecast was prepared to incorporate all the assumptions of the High Use scenario plus adjustments to account for data base errors or to introduce alternative regional forecasts provided by the Corps of Engineers.

(2) Based on Federal Emergency Management Agency forecast.

(3) Great Lakes share drops 10%.

(4) Overseas and Canadian destinations.

(5) Based on National Coal Association forecast as modified by DRI.

(6) An additional demonstration plant (not included in these numbers) on the Monongahela is operated from 1983 to 1990 and consumes 3,000,000 to 6,000,000 tons of coal each year. However, after 1990, it is discontinued.

(7) One of these seven pipelines (ETSI) will divert 4.5 million tons of coal from the waterways by 2003.

Source: NWS, Evaluation of the Present Navigation System, 1981.

EXHIBIT IV

NATIONAL WATERWAYS STUDY

UNCONSTRAINED FORECASTS OF
POTENTIAL WATERBORNE TONNAGE
PASSING THROUGH EACH NWS REGION
(MILLIONS OF SHORT TONS)

REGION	1977	2003 BASE-LINE	HIGH USE(1)	LOW USE	BAD ENERGY	HIGH COAL EXPORTS
UPPER MISSISSIPPI RIVER	30.9	66.0	68.7	58.8	67.9	68.7
LOWER UPPER MISSISSIPPI	77.5	162.0	167.3	147.7	163.3	169.6
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	123.6	222.3	231.0	190.7	235.9	246.6
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	344.4	534.9	548.7	492.1	543.8	591.4
ILLINOIS WATERWAY	60.4	103.5	106.4	95.6	108.4	106.4
MISSOURI RIVER	6.7	7.8	7.8	7.4	7.0	7.8
OHIO RIVER	172.5	307.5	345.2	280.3	324.5	359.6
TENNESSEE RIVER	26.5	66.9	79.5	61.7	67.3	86.4
ARKANSAS RIVER	9.4	14.4	15.0	10.8	16.5	15.8
GULF COAST WEST	341.3	385.7	389.0	376.9	362.2	404.1
GULF COAST EAST	108.7	152.1	168.2	141.3	140.5	168.5
MOBILE RIVER AND TRIBUTARIES	43.7	119.0	137.4	108.9	120.4	177.6
SOUTH ATLANTIC COAST	69.8	69.6	71.1	65.1	63.8	71.1
MIDDLE ATLANTIC COAST	436.8	438.0	469.2	409.8	427.5	514.7
NORTH ATLANTIC COAST	87.4	68.9	68.9	64.6	63.0	68.9
GREAT LAKES/SEAWAY	189.9	385.7	411.1	345.2	392.7	411.1
WASHINGTON/OREGON COAST	68.4	121.2	121.2	109.4	113.0	132.9
COLUMBIA-SNAKE WATERWAY	43.5	58.6	58.6	57.9	54.6	58.6
CALIFORNIA COAST	138.3	143.6	143.6	115.0	113.3	153.4
ALASKA	28.8	86.2	86.2	86.4	95.4	86.2
HAWAII	15.3	21.5	21.5	20.9	21.1	21.5
CARIBBEAN	89.8	74.5	74.5	49.4	68.0	74.5
ELIMINATE OVERCOUNTING(2)	(598.5)	(1,024.0)	(1,062.6)	(916.2)	(1,055.8)	(1,105.6)
TOTAL	1,914.9	2,585.6	2,727.2	2,379.8	2,514.3	2,889.6

Notes: (1)The unconstrained forecasts of waterways tonnage under a defense emergency is not shown in this Exhibit because the emergency is assumed to take place during 1985-1995. After 1990, the forecast of waterways tonnage returns to the levels of the high use scenario.

(2)It is necessary to eliminate the overcounting of individual shipments that pass through more than one region.

Source: NWS, Evaluation of the Present Navigation System, 1981.

EXHIBIT V

NATIONAL WATERWAYS STUDY

UNCONSTRAINED FORECASTS OF POTENTIAL WATERBORNE AGRICULTURE TONNAGE PASSING THROUGH EACH REGION(1)
(MILLIONS OF SHORT TONS)

REGION	1977	2003 BASE-LINE(2)	2003 LOW USE	2003 BAD ENERGY
UPPER MISSISSIPPI RIVER	13.2	33.3	29.2	36.1
LOWER UPPER MISSISSIPPI RIVER	36.0	78.6	68.5	83.1
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	46.4	102.2	89.9	103.3
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	101.8	226.7	200.0	228.6
ILLINOIS WATERWAY	17.6	37.4	32.3	42.9
MISSOURI RIVER	2.0	3.6	3.2	3.0
OHIO RIVER	7.2	12.2	11.1	12.7
TENNESSEE RIVER	2.4	3.5	3.1	2.9
ARKANSAS RIVER	1.2	2.4	2.3	1.8
GULF COAST WEST	24.7	57.0	56.1	54.9
GULF COAST EAST	6.5	12.1	10.9	11.4
MOBILE RIVER AND TRIBUTARIES	2.8	11.4	10.8	9.3
SOUTH ATLANTIC COAST	2.9	5.8	5.7	5.7
MIDDLE ATLANTIC COAST	24.8	53.0	49.4	57.6
NORTH ATLANTIC COAST	1.0	2.3	2.2	2.2
GREAT LAKES/SEAWAY	12.1	27.2	23.2	28.0
WASHINGTON/OREGON COAST	3.0	12.8	11.2	14.7
COLUMBIA-SNAKE WATERWAY	10.4	22.0	22.2	19.3
CALIFORNIA COAST	9.5	22.9	22.0	23.5
ALASKA	0.5	0.9	0.9	0.9
HAWAII	3.3	6.3	6.3	6.4
CARIBBEAN	3.0	5.0	5.0	5.1
ELIMINATE OVERCOUNTING(3)	(129.9)	(280.0)	(246.8)	(290.4)
TOTAL	202.4	458.6	418.7	463.0

Notes: (1)The agriculture industry includes reporting commodities, for farm products and food and kindred products.
(2)The high use and high coal export forecasts are identical to the baseline forecast for agriculture.
(3)It is necessary to eliminate the overcounting of individual shipments that pass through more than one region.

Source: NWS, Evaluation of the Present Navigation System, 1981.

NATIONAL WATERWAYS STUDY

UNCONSTRAINED FORECASTS OF POTENTIAL WATERBORNE PETROLEUM TONNAGE PASSING THROUGH EACH REGION(1)
(MILLIONS OF SHORT TONS)

REGION	1977	2003 BASE-LINE(2)	2003 LOW USE	2003 BAD ENERGY
UPPER MISSISSIPPI RIVER	3.7	3.5	3.3	3.2
LOWER UPPER MISSISSIPPI RIVER	12.8	12.2	11.7	11.3
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	27.9	23.5	22.1	21.3
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	158.1	136.2	139.1	120.4
ILLINOIS WATERWAY	9.0	7.8	7.4	7.2
MISSOURI RIVER	0.4	0.6	0.6	0.5
OHIO RIVER	22.7	18.8	17.8	17.8
TENNESSEE RIVER	3.6	4.7	2.9	2.9
ARKANSAS RIVER	2.1	1.3	1.1	1.1
GULF COAST WEST	240.6	196.7	200.0	168.7
GULF COAST EAST	45.8	36.2	33.1	30.5
MOBILE RIVER AND TRIBUTARIES	10.3	12.1	11.[illegible]	11.3
SOUTH ATLANTIC COAST	34.9	26.4	24.[illegible]	23.1
MIDDLE ATLANTIC COAST	298.6	177.6	160.[illegible]	154.9
NORTH ATLANTIC COAST	79.6	51.6	4[illegible].[illegible]	46.7
GREAT LAKES/SEAWAY	11.5	7.[illegible]	7.4	7.2
WASHINGTON/OREGON COAST	24.0	57.[illegible]	48.3	47.7
COLUMBIA-SNAKE WATERWAY	6.2	5.2	4.3	4.1
CALIFORNIA COAST	106.5	72.6	44.3	42.3
ALASKA	21.9	75.1	75.8	84.6
HAWAII	8.7	7.9	7.9	7.8
CARIBBEAN	77.8	51.5	27.3	45.3
ELIMINATE OVERCOUNTING(3)	(248.5)	(291.7)	(251.6)	(257.8)
TOTAL	958.2	722.8	646.7	602.1

Notes: (1) The petroleum industry includes reporting commodities, for crude petroleum, and petroleum and coal products.
(2) The high use, high coal export, and baseline forecasts are identical for petroleum.
(3) It is necessary to eliminate the overcounting of individual shipments that pass through more than one region.

Source: NWS, Evaluation of the Present Navigation System, 1981.

NATIONAL WATERWAYS STUDY

UNCONSTRAINED FORECASTS OF POTENTIAL WATERBORNE COAL TONNAGE PASSING THROUGH EACH REGION
(MILLIONS OF SHORT TONS)

		2003				
REGION	1977	BASE-LINE	HIGH USE	LOW USE	BAD ENERGY	HIGH COAL EXPORTS
UPPER MISSISSIPPI RIVER	6.9	19.5	22.3	16.5	18.3	22.3
LOWER UPPER MISSISSIPPI	10.7	41.3	46.6	37.8	38.4	48.9
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	11.9	43.5	52.3	25.8	57.4	67.8
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	11.8	46.0	59.8	26.5	68.7	102.6
ILLINOIS WATERWAY	9.6	19.2	22.1	18.5	19.3	22.1
MISSOURI RIVER	0.0	0.0	0.0	0.0	0.0	0.0
OHIO RIVER	100.1	228.2	265.9	205.0	246.6	280.2
TENNESSEE RIVER	10.1	44.4	56.9	42.8	45.8	63.9
ARKANSAS RIVER	0.5	5.3	5.8	1.9	8.0	6.7
GULF COAST WEST	0.3	8.8	12.2	0.3	17.3	27.2
GULF COAST EAST	8.7	40.8	45.9	34.5	34.8	46.3
MOBILE RIVER AND TRIBUTARIES	12.7	52.3	70.7	51.4	59.1	111.0
SOUTH ATLANTIC COAST	0.0	0.0	0.0	0.0	0.0	0.0
MIDDLE ATLANTIC COAST	37.3	89.1	120.3	91.3	102.0	165.7
NORTH ATLANTIC COAST	0.0	3.0	3.0	3.0	3.0	3.0
GREAT LAKES/SEAWAY	42.6	80.4	105.7	79.3	97.9	105.7
WASHINGTON/OREGON COAST	0.0	0.0	0.0	0.0	0.0	0.0
COLUMBIA-SNAKE WATERWAY	0.0	0.0	0.0	0.0	0.0	0.0
CALIFORNIA COAST	0.0	0.0	0.0	0.0	0.0	9.8
ALASKA	0.0	0.0	0.0	0.0	0.0	0.0
HAWAII	0.0	0.0	0.0	0.0	0.0	0.0
CARIBBEAN	0.0	0.0	0.0	0.0	0.0	0.0
ELIMINATE OVERCOUNTING(1)	(51.4)	(208.1)	(246.7)	(158.6)	(239.3)	(278.0)
TOTAL	211.8	513.7	642.8	476.0	577.3	805.2

Note: (1) It is necessary to eliminate the overcounting of individual shipments that pass through more than one region.

Source: NWS, Evaluation of the Present Navigation System, 1981.

EXHIBIT VIII

NATIONAL WATERWAYS STUDY

UNCONSTRAINED FORECASTS OF POTENTIAL WATERBORNE METALS TONNAGE PASSING THROUGH EACH REGION(1)
(MILLIONS OF SHORT TONS)

REGION	1977	2003 BASE-LINE(2)	2003 LOW USE	2003 BAD ENERGY
UPPER MISSISSIPPI RIVER	0.4	0.6	0.6	0.6
LOWER UPPER MISSISSIPPI RIVER	3.0	5.0	5.4	4.9
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	7.0	10.7	11.6	10.6
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	19.3	35.1	37.5	35.3
ILLINOIS WATERWAY	11.8	21.0	19.9	20.6
MISSOURI RIVER	0.1	0.1	0.2	0.1
OHIO RIVER	6.0	8.4	7.7	8.2
TENNESSEE RIVER	1.3	2.1	1.6	2.1
ARKANSAS RIVER	1.1	1.7	1.7	1.6
GULF COAST WEST	13.2	22.7	24.1	22.6
GULF COAST EAST	2.3	3.8	4.1	3.8
MOBILE RIVER AND TRIBUTARIES	11.6	30.2	22.7	28.0
SOUTH ATLANTIC COAST	4.5	7.4	7.1	7.1
MIDDLE ATLANTIC COAST	23.1	32.5	31.0	32.4
NORTH ATLANTIC COAST	1.1	1.6	2.2	1.7
GREAT LAKES/SEAWAY	106.4	236.5	206.1	228.9
WASHINGTON/OREGON COAST	1.1	1.8	2.2	1.9
COLUMBIA-SNAKE WATERWAY	0.7	1.4	2.0	1.5
CALIFORNIA COAST	4.3	8.4	11.1	8.7
ALASKA	0.6	0.8	0.9	0.8
HAWAII	0.2	0.2	0.3	0.2
CARIBBEAN	1.6	2.4	2.6	2.4
ELIMINATE OVERCOUNTING(3)	(31.9)	(59.3)	(57.3)	(57.9)
TOTAL	188.7	374.9	346.0	365.9

Notes: (1)The metals industry includes reporting commodities, metallic ores, and primary metals products, and analytical commodity, limestone.
(2)Baseline, high use, and high coal export scenarios are identical for this industry group.
(3)It is necessary to eliminate the overcounting of individual shipments that pass through more than one region.

Source: NWS, Evaluation of the Present Navigation System, 1981.

EXHIBIT IX

NATIONAL WATERWAYS STUDY

UNCONSTRAINED FORECASTS OF POTENTIAL WATERBORNE
CHEMICALS/FERTILIZER TONNAGE PASSING THROUGH EACH REGION(1)
(MILLIONS OF SHORT TONS)

REGION	1977	2003 BASE-LINE	HIGH USE(2)	LOW USE	BAD ENERGY
UPPER MISSISSIPPI RIVER	2.6	5.1	5.1	5.2	5.8
LOWER UPPER MISSISSIPPI RIVER	8.1	15.6	15.6	15.3	16.5
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	15.2	27.2	27.2	26.3	28.2
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	37.1	66.0	65.8	64.6	68.1
ILLINOIS WATERWAY	4.9	9.8	9.8	9.4	10.3
MISSOURI RIVER	0.5	0.9	0.9	0.9	0.7
OHIO RIVER	10.9	22.4	22.4	20.1	22.1
TENNESSEE RIVER	2.5	6.0	6.0	5.7	6.0
ARKANSAS RIVER	0.6	1.2	1.2	1.2	1.3
GULF COAST WEST	35.1	60.1	60.1	57.0	58.7
GULF COAST EAST	33.7	42.5	53.5	42.1	44.3
MOBILE RIVER AND TRIBUTARIES	1.5	6.5	6.5	6.2	6.5
SOUTH ATLANTIC COAST	6.9	8.5	10.0	8.2	7.2
MIDDLE ATLANTIC COAST	11.6	20.3	20.3	19.6	19.6
NORTH ATLANTIC COAST	0.9	1.6	1.6	1.5	1.6
GREAT LAKES/SEAWAY	1.2	2.4	2.4	2.1	2.1
WASHINGTON/OREGON COAST	2.3	4.2	4.2	4.0	4.4
COLUMBIA-SNAKE WATERWAY	2.1	3.7	3.7	3.4	3.7
CALIFORNIA COAST	3.5	5.3	5.3	5.3	5.2
ALASKA	0.8	1.1	1.1	1.1	1.2
HAWAII	0.3	0.4	0.4	0.4	0.3
CARIBBEAN	4.3	8.8	8.8	8.2	8.6
ELIMINATE OVERCOUNTING(3)	(73.9)	(143.6)	(142.4)	(137.95)	(146.5)
TOTAL	112.7	176.0	189.5	170.3	175.9

Notes: (1)The chemicals/fertilizer industry includes reporting commodity, chemicals, and analytical commodities, phosphate rock, and other fertilizers as well as sulfur.
(2)The high coal export forecast is identical to the high use forecast.
(3)It is necessary to eliminate the overcounting of individual shipments that pass through more than one region.

Source: NWS, Evaluation of the Present Navigation System, 1981.

EXHIBIT X

NATIONAL WATERWAYS STUDY

UNCONSTRAINED FORECASTS OF
POTENTIAL WATERBORNE FOREST PRODUCTS
TONNAGE PASSING THROUGH EACH REGION(1)
(MILLIONS OF SHORT TONS)

REGION	1977	BASELINE IN 2003(2)
UPPER MISSISSIPPI RIVER	0.0	0.0
LOWER UPPER MISSISSIPPI RIVER	0.2	0.3
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	0.9	1.2
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	1.9	3.4
ILLINOIS WATERWAY	0.2	0.3
MISSOURI RIVER	0.0	0.0
OHIO RIVER	0.1	0.1
TENNESSEE RIVER	0.5	0.7
ARKANSAS RIVER	0.1	0.2
GULF COAST WEST	0.9	1.6
GULF COAST EAST	0.7	1.1
MOBILE RIVER AND TRIBUTARIES	0.9	1.3
SOUTH ATLANTIC COAST	4.0	5.6
MIDDLE ATLANTIC COAST	3.7	4.3
NORTH ATLANTIC COAST	0.4	0.5
GREAT LAKES/SEAWAY	1.0	1.4
WASHINGTON/OREGON COAST	26.6	24.9
COLUMBIA-SNAKE WATERWAY	17.4	19.4
CALIFORNIA COAST	3.9	3.5
ALASKA	3.4	4.0
HAWAII	0.5	0.7
CARIBBEAN	0.5	0.8
ELIMINATE OVERCOUNTING(3)	(3.4)	(4.9)
TOTAL	64.4	70.5

Notes: (1)The forest products industry includes reporting commodities, lumber and wood products and pulp, paper, and allied products.
(2)Only one forecast was developed for this industry.
(3)It is necessary to eliminate the overcounting of individual shipments that pass through more than one region.

Source: NWS, Evaluation of the Present Navigation System, 1981.

EXHIBIT XI

NATIONAL WATERWAYS STUDY

UNCONSTRAINED FORECASTS OF POTENTIAL WATERBORNE TONNAGE OF OTHER COMMODITIES PASSING THROUGH EACH REGION(1)
(MILLIONS OF SHORT TONS)

REGION	1977	2003 BASE-LINE(2)	2003 LOW USE	2003 BAD ENERGY
UPPER MISSISSIPPI RIVER	4.1	3.9	3.9	3.9
LOWER UPPER MISSISSIPPI RIVER	6.7	8.9	8.7	8.8
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	14.2	14.1	14.0	14.1
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	14.2	19.9	19.4	19.6
ILLINOIS WATERWAY	7.4	7.9	7.8	7.8
MISSOURI RIVER	3.7	2.6	2.6	2.6
OHIO RIVER	27.4	21.8	21.6	21.7
TENNESSEE RIVER	5.1	4.6	4.6	4.6
ARKANSAS RIVER	3.7	2.5	2.5	2.5
GULF COAST WEST	26.4	38.8	38.0	38.5
GULF COAST EAST	10.3	15.0	15.0	14.8
MOBILE RIVER AND TRIBUTARIES	4.9	6.0	5.9	5.9
SOUTH ATLANTIC COAST	6.5	15.8	14.3	13.5
MIDDLE ATLANTIC COAST	37.5	61.0	54.1	56.7
NORTH ATLANTIC COAST	4.4	8.4	6.9	7.3
GREAT LAKES/SEAWAY	14.9	30.1	25.7	27.3
WASHINGTON/OREGON COAST	11.3	19.9	18.8	19.5
COLUMBIA-SNAKE WATERWAY	6.7	6.9	6.6	6.8
CALIFORNIA COAST	10.5	30.8	28.8	30.2
ALASKA	1.6	4.2	3.7	4.0
HAWAII	2.3	6.1	5.5	5.8
CARIBBEAN	2.4	6.0	5.6	5.9
ELIMINATE OVERCOUNTING(3)	(49.5)	(66.1)	(62.4)	(62.2)
TOTAL	176.7	269.1	251.6	259.6

Notes: (1)The "other" grouping includes reporting commodities, nonmetallic minerals (except limestone, phosphate rock, and sulfur), stone, clay, glass, and concrete products, waste and scrap, and "other" commodities.
(2)High use and high coal export forecasts are identical to baseline for this group of commodities.
(3)It is necessary to eliminate the overcounting of individual shipments that pass through more than one region.

Source: NWS, Evaluation of the Present Navigation System, 1981.

HAZARDS TO NAVIGATION

REGION	SEGMENT	RIVER-MILE/ HARBOR	BRIDGES	LOCKS(1)	CHANNEL CONFIGU-RATION(2)	CONGESTED TRAFFIC AREAS
UPPER MISSISSIPPI RIVER	UPPER MISSISSIPPI	274		X		
		310	X			
		360-365	X			
		384	X			
		403-405	X			
		535	X			
		578-583	X			
		697-700	X			
		723-726	X			
LOWER UPPER MISSISSIPPI RIVER	MIDDLE MISSISSIPPI	44	X			
		172-184	X			
		203		X		
LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE	LOWER MIDDLE MISSISSIPPI;	735-755	X			
	UPPER LOWER MISSISSIPPI	361-365	X			
		428-445	X		X	
		531	X		X	
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	MISSISSIPPI RIVER: BATON ROUGE TO NEW ORLEANS	165-175			X	
		210-225			X	
		225-235	X			
		109-235				X
	MISSISSIPPI RIVER: NEW ORLEANS TO GULF	75-85			X	
		85-109	X			
		0-109				X
	OLD AND ATCHAFALAYA RIVERS	5	X			
		30	X			
		41	X			
	BATON ROUGE TO MORGAN CITY	0-3	X			
		0-64				X
ILLINOIS WATERWAY	ILLINOIS WATERWAY	150-155	X			
		160-165	X			
		239-240	X			
		244-247				X
		270-272	X			
		286-289	X			
		290-293	X			
OHIO RIVER	UPPER OHIO RIVER	0-15		X		X
		32		X		X
		53-54		X		X
		95		X		
		184-185		X		
		254-270(3)				X
	MIDDLE OHIO RIVER	279		X		
		304-328				X
		340-350		X		
		460-485	X			
		531-532		X		
	LOWER-OHIO RIVER - THREE	597-607	X			X
		774-785		X		X
	LOWER OHIO RIVER - ONE	932-943			X	
	MONONGAHELA RIVER	0-11				X
	GREEN RIVER	8-10	X			
		71	X			
		80	X			
	CUMBERLAND RIVER	126	X			
		185	X			
		189-193	X			

NATIONAL WATERWAYS STUDY

HAZARDS TO NAVIGATION (CONT'D.)

REGION	SEGMENT	RIVER-MILE/ HARBOR	BRIDGES	LOCKS(1)	CHANNEL CONFIGU-RATION(2)	CONGESTED TRAFFIC AREAS
TENNESSEE RIVER	UPPER TENNESSEE RIVER	301-306				X
		414	X			
		462-471				X
	LOWER TENNESSEE RIVER	66	X			
GULF COAST WEST	GIWW WEST ONE: NEW ORLEANS TO CALCASIEU RIVER	0-7(4)	X			
		0-6(5)	X			
		13	X			
		35	X			
		49-50	X			
		55-60	X			
		85-241				X
		113	X			
		134	X			
		231	X			
		1(6)	X			
	GIWW WEST TWO: CALCASIEU TO CORPUS CHRISTI	244	X			
		276-289				X
		353	X			
		356-358	X			
		393-405	X	X		
		418	X			
		440-442	X			
		533	X			
		36(7)	X			
		Freeport	X	X		
	HOUSTON SHIP CHANNEL	0-49			X	X
GULF COAST EAST	GIWW EAST ONE: NEW ORLEANS TO MOBILE BAY	6-8	X			X
		7-10(8)	X			X
		MISSISSIPPI SOUND			X	
		PASCAGOULA			X	
	GIWW EAST TWO: MOBILE BAY TO ST. MARKS, FLORIDA	MOBILE				X
MOBILE RIVER AND TRIBUTARIES	BLACK WARRIOR - MOBILE RIVER	13	X			
		165	X			
		173	X			
		202	X			
		217			X	
		219	X			
		265	X			
		267	X			
		385			X	
		413	X			
		416	X			
		LOCUST FORK			X	
		MOBILE	X			

NATIONAL WATERWAYS STUDY

HAZARDS TO NAVIGATION (CONT'D.)

REGION	SEGMENT	RIVER-MILE/ HARBOR	BRIDGES	LOCKS(1)	CHANNEL CONFIGU-RATION(2)	CONGESTED TRAFFIC AREAS
SOUTH ATLANTIC COAST	FLORIDA/GEORGIA COAST	7				X
		26-27	X			
		SAVANNAH				X
MIDDLE ATLANTIC COAST	CHESAPEAKE AND DELAWARE BAYS	2-3	X			X
		5	X			X
		0-3(9)				X
		BALTIMORE				X
		PALMYRA	X			
	NEW JERSEY-NEW YORK COASTS	NEWARK	X			
NORTH ATLANTIC COAST	NORTH ATLANTIC COAST	NEW HAVEN	X			
		BOSTON	X			
		PORTLAND	X			
GREAT LAKES/ ST. LAWRENCE SEAWAY	LAKE ONTARIO AND SEAWAY	MASSENA				X
		JOHNSTOWN			X	
	LAKE ERIE	BUFFALO	X			
		CLEVELAND	X			
		TOLEDO	X			
	LAKE HURON	ROUGE R.	X			
		ST. MARYS R.				X
	LAKE MICHIGAN	CALUMET R.	X			
WASHINGTON/OREGON COAST	PUGET SOUND	SEATTLE	X			X
		TACOMA	X			
COLUMBIA-SNAKE WATERWAY	UPPER COLUMBIA SNAKE WATERWAY	146		X		
	LOWER COLUMBIA-SNAKE WATERWAY	106	X			
		0-145				X
CALIFORNIA COAST	SAN FRANCISCO BAY AREA;	SAN FRANCISCO	X			X
	CENTRAL/SOUTH CALIFORNIA	LA/LONG BEACH				X
ALASKA	SOUTHEAST ALASKA					X
HAWAII	HAWAII	HONOLULU	X			

Notes: (1)Includes other waterway structures as well.
(2)Includes bends and narrow channels; relative to traffic characteristics.
(3)Includes the Kanawha River as well.
(4)Algiers route.
(5)Harvey Canal.
(6)Barataria Waterway.
(7)Calcasieu River.
(8)Inner Harbor Navigation Canal.
(9)Eastern Branch of Elizabeth River.

Source: NWS, Evaluation of the Present Navigation System, 1981.

NATIONAL WATERWAYS STUDY

EXHIBIT XIII

ESTIMATED COST OF
STRUCTURAL ACTIONS FOR LOCKS(1)

NWS REGION	LOCK NAME	TYPE OF ACTION: CONSTRUCT AN ADDITIONAL CHAMBER	TYPE OF ACTION: REPLACE AN EXISTING CHAMBER	DIMENSIONS OF NEW CHAMBERS(1): WIDTH (FEET)	DIMENSIONS OF NEW CHAMBERS(1): LENGTH (FEET)	INCREMENTAL COSTS (MILLIONS OF 1977 DOLLARS)(2): CONSTRUCTION	INCREMENTAL COSTS (MILLIONS OF 1977 DOLLARS)(2): ANNUAL OPERATION AND MAINTENANCE
UPPER	L&D 25		X	110	1,200	$90.0	0.0
MISSISSIPPI	L&D 24		X	110	1,200	90.0	0.0
RIVER	L&D 22		X	110	1,200	90.0	0.0
	L&D 21		X	110	1,200	90.0	0.0
	L&D 20		X	110	1,200	90.0	0.0
	L&D 16		X	110	1,200	90.0	0.0
	L&D 15		X	110	1,200	90.0	0.0
				110	1,200	90.0	0.0
LOWER UPPER MISSISSIPPI	L&D 26	X		110	1,200	97.0	$0.2
RIVER			X				
ILLINOIS	LA GRANGE		X	110	1,200	77.0	0.0
WATERWAY	PEORIA		X	110	1,200	79.0	0.0
	STARVED ROCK		X	110	1,200	77.0	0.0
	MARSEILLES		X	110	1,200	85.0	0.0
	DRESDEN ISLAND		X	110	1.200	63.0	0.0
	BRANDON ROAD		X	110	1,200	63.0	0.0
	LOCKPORT		X	110	1,200	63.0	0.0
OHIO RIVER	EMSWORTH		X	110	1,200	100.0	0.1
	DASHIELDS		X	110	1,200	90.0	0.1
	MONTGOMERY		X	110	1,200	200.0	0.1
	GALLIPOLIS		X(3)	110	1,200	205.0	0.1
	MCALPINE		X	110	1,200	125.0	0.2
	NEWBURGH		X	110	1,200	120.0	0.2
	UNIONTOWN		X	110	1,200	105.0	0.2
	MONONGAHELA L&D 3		X	110	720	45.0	0.0
	MONONGAHELA L&D 4		X	110	720	45.0	0.0
	MONONGAHELA L&D 7		X	110	720	45.0	0.0
	MONONGAHELA L&D 8		X	110	720	45.0	0.0
	WINFIELD		X	110	600	50.0	0.0
GULF COAST	HARVEY		X	110	1,200	150.0	0.1
WEST	ALGIERS		X	110	1,200	150.0	0.1
GULF COAST EAST	INNER HARBOR		X(4)	110	1,200	70.0	0.2
MOBILE RIVER	WARRIOR		X	110	600	70.0	0.1
AND	BANKHEAD		X	110	600	70.0	0.1
TRIBUTARIES	HOLT		X	110	600	70.0	0.1
	OLIVER		X	110	600	70.0	0.1
	DEMOPOLIS		X	110	600	70.0	0.1
	COFFEEVILLE		X	110	600	60.0	0.0
GREAT LAKES/	WELLAND CANAL 1	X		130	1,200	-(5)	-(5)
ST. LAWRENCE	WELLAND CANAL 2	X		130	1,200	-(5)	-(5)
SEAWAY/	WELLAND CANAL 3	X		130	1,200	-(5)	-(5)
NEW YORK	WELLAND CANAL 7	X		130	1,200	-(5)	-(5)
STATE WATER-	WELLAND CANAL 8	X		130	1,200	-(5)	-(5)
WAYS	SAULT ST. MARIE	X		130	1,200	102.0	0.2
COLUMBIA-SNAKE WATERWAY/ WILLAMETTE RIVER	BONNEVILLE		X	86	675	56.0	0.1

Notes: (1)The dimensions are shown only to illustrate how costs of actions were estimated. These are not necessarily recommended sizes.
(2)Costs assumes actions taken in 1977. Real costs would be greater in 1977 dollars due to greater than inflation rate increases in construction costs.
(3)This action incorporates a bypass canal with a new 100' x 1,200' chamber and a new 110' x 600' chamber.
(4)Simply replacing the existing chamber with a larger chamber would not substantially increase capacity at this site due to the peculiar nature of the traffic. Therefore a new larger chamber is provided to increase capacity and the old chamber is retained to continue to serve traffic that can use it effectively.
(5)Canadian owned and operated locks. No costs included in this report.

Source: NWS, Evaluation of Alternative Future Strategies for Action, 1981.

EXHIBIT XIV

NATIONAL WATERWAYS STUDY

COSTS FOR IMPLEMENTING INEXPENSIVE ACTIONS TO MITIGATE SAFETY HAZARDS

REGION	NUMBER OF ACTIONS TAKEN AT				INCREMENTAL COSTS (MILLION OF 1977 DOLLARS)	
	CONGESTED AREAS(1)	BRIDGES(2)	LOCKS(3)	CHANNELS(4)	CONSTRUCTION	ANNUAL OPERATING
UPPER MISSISSIPPI RIVER	-	8	1	1	$ 10.0	0.0
LOWER UPPER MISSISSIPPI RIVER	-	8	0	1	17.0	0.0
LOWER MISSISSIPPI RIVER	-	7	0	2	15.0	0.0
LOWER MISSISSIPPI RIVER: BATON ROUGE TO GULF	3	8	0	3	15.0	$ 1.5
ILLINOIS WATERWAY	1	17	0	2	24.0	0.5
OHIO RIVER	6	12	8	1	21.0	3.0
TENNESSEE RIVER	2	2	0	0	3.0	1.0
GULF COAST WEST	3	28	2	0	33.0	1.5
GULF COAST EAST	2	5	0	2	12.0	1.5
MOBILE RIVER AND TRIBUTARIES	-	10	0	3	14.0	0.0
SOUTH ATLANTIC COAST	2	3	0	0	6.0	1.5
MIDDLE ATLANTIC COAST	2	10	0	0	20.0	2.0
NORTH ATLANTIC COAST	-	5	0	0	10.0	0.0
GREAT LAKES/SEAWAY	2	28	0	1	61.0	1.5
WASHINGTON/OREGON COAST	1	6	0	0	11.0	1.0
COLUMBIA-SNAKE WATERWAY	1	1	1	0	3.0	0.5
CALIFORNIA COAST	2	2	0	0	4.0	1.5
ALASKA	1	0	0	0	0.0	0.5
HAWAII	-	1	0	0	2.0	0.0
TOTAL	28	161	12	17	$281.0	$17.5

Notes: (1) Installation of more sophisticated vessel traffic control systems.
(2) Includes such actions as installation of fenders, radar transponders, and radar reflectors.
(3) Actions include installation of mooring cells and/or guidewalls.
(4) Placement of aids to navigation.

Source: NWS, Evaluation of Alternative Future Strategies for Action, 1981.

EXHIBIT XV

NATIONAL WATERWAYS STUDY

ACTION DECISION RULES FOR STRATEGIES I THROUGH IV

DECISION RULES	STRATEGY I(1)	STRATEGY II(1)	STRATEGY III	STRATEGY IV
1. OPERATION, MAINTENANCE AND REHABILITATION	MEET ALL O&M NEEDS FOR CLASS "A" SEGMENTS AND MAJOR PORTS.(2) IF FUNDS AVAILABLE, MEET O&M NEEDS FOR CLASS "B" SEGMENTS. IF FUNDS AVAILABLE MEET O&M NEEDS FOR CLASS "C" SEGMENTS, SECONDARY PORTS AND SIDE CHANNELS.	SAME AS I, EXCEPT ACTIONS FOR ADDING LOCK CAPACITY IN CLASS "A" SEGMENTS HAVE PRIORITY OVER THE NEEDS FOR OPERATIONS AND MAINTENANCE OF CLASS "B" AND "C" SEGMENTS AS WELL AS SECONDARY PORTS.(2)	FUND OF CHANNEL MAINTENANCE NEEDS TO MAINTAIN 1975-RELIABILITY AND COMPLETE FUNDING OPERATIONS AND REHABILITATION NEEDS.	SAME AS III, BUT FUND ANNUAL DEFERRED MAINTENANCE DREDGING AS WELL.
2. LOCK CONSTRUCTION	ADD LOCK CAPACITY AT 95% UTILIZATION OF PRACTICAL CAPACITY -- IF ADEQUATE FUNDS AVAILABLE.	SAME AS I, BUT LOCK CAPACITY ACTIONS FOR CLASS "A" SEGMENTS ARE MADE BEFORE MEETING THE OPERATION AND MAINTENANCE NEEDS OF CLASS "B" AND "C" SEGMENTS.	ADD LOCK CAPACITY AT 95% UTILIZATION WHEREVER IT OCCURS.	ADD LOCK CAPACITY AT 85% UTILIZATION WHEREVER IT OCCURS. REPLACE SELECTED OBSOLETE LOCKS.
3. SAFETY	TAKE MINOR STRUCTURAL AND NONSTRUCTURAL ACTIONS IN REGIONS WITH TRAFFIC GROWTH OF NO LESS THAN 10,000,000 TONS BY YEAR 2003, IF ADEQUATE FUNDS AVAILABLE.	SAME AS I, BUT SAFETY ACTIONS FOR REGIONS WITH TRAFFIC GROWTH OF NO LESS THAN 10,000,000 TONS ARE GIVEN PRIORITY OVER THE NEED FOR OPERATION AND MAINTENANCE OF CLASS "C" SEGMENTS.	TAKE MINOR AND NONSTRUCTURAL ACTIONS IN REGIONS WITH TRAFFIC GROWTH OF NO LESS THAN 10,000,000 TONS BY THE YEAR 2003.	SIMILAR TO III, BUT TAKE SOME MAJOR STRUCTURAL ACTIONS TO ALTER OR REPLACE BRIDGES AND WIDEN REACHES.
4. CHANNEL AND PORT DEEPENING	NO ACTIONS.	NO ACTIONS.	NO ACTIONS.	DEEPEN MISSISSIPPI, ILLINOIS, AND OHIO RIVERS. DEEPEN GALVESTON, NEW ORLEANS, BATON ROUGE, MOBILE, NORFOLK AND BALTIMORE TO 50' OR MORE. WIDEN THE TOMBIGBEE RIVER SOUTH OF DEMOPOLIS.

Notes: (1) It is assumed that the Red River and Tennessee-Tombigbee projects and the single 1,200' lock replacement project at Lock and Dam 26 are completed as part of the "present system." These projects will prevent any new major actions for lock construction and safety from being taken under Strategies I and II until after 1990 due to assumed funding limits.

(2) Class A, B, and C inland waterway segments have been grouped according to projected operations and maintenance costs per ton-mile of projected traffic in 2003. Class "C" inland segments have an operations and maintenance cost per ton-mile of 5 mills or more. Class "B" segments have a level of 1.5 to 5 mills and Class "A" inland segments have a ratio of 1.5 mills or less. Side channels are short spurs that do not carry through traffic. Minor ports are all those on the Great Lakes or Coasts that handled less than 1,000,000 tons in 1977.

Source: NWS, Evaluation of Alternative Future Strategies for Action, 1981.

EXHIBIT XVI

NATIONAL WATERWAYS STUDY

SUMMARY OF ACTIONS FOR STRATEGY I

	Scenario(1) Base-Line	High Use	Low Use	Bad Energy
1. Completion of Present System	X	X	X	X
2. Normal Operations and Maintenance				
A, B, Major Ports	*	*	*	*
C	*	*	*	*
Minor Ports and Side Channels	*	*	*	*
3. Managerial Actions at Congested Locks	X	X	X	X
4. Channel Maintenance (Dredging)				
A, B, Major Ports	*	*	*	*
C	*	*	*	*
Minor Ports and Side Channels	*	*	*	*
5. Rehabilitation				
A, B, Major Ports	*	*	*	*
C	*	*	*	*
6. Minor Safety Actions				
7. Structural Actions at Locks				
PRIMARY CONSTRAINING LOCKS				
Mississippi Lock and Dam 26	X	X	X	X
Welland Canal (5 Locks)	X	X	X	X
Gallipolis				
Demopolis				
Uniontown				
Sault Ste. Marie				
SECONDARY CONSTRAINING LOCKS				
La Grange				
Peoria				
Marseilles				
Mississippi Lock and Dam 22				
Oliver				
Warrior				
Holt				
Newburgh				
McAlpine				
Coffeeville				
Bankhead				
POTENTIALLY CONSTRAINING LOCKS				
Inner Harbor				
Montgomery				
Ohio Locks and Dam 52				
Bonneville				
TOTAL LOCK ACTIONS	6	6	6	6

* Funding requirements for normal operations and maintenance, channel maintenance, and rehabilitation for the complete system exceed the budget limit by the year 2003. Since Strategy I provides no priorities for these categories of funding in its decision rules, some actions are deferred each year after the year 2000, and the system would be allowed to deteriorate.

X This class of actions taken.

Note: (1) No evaluation of high coal export or defense scenarios was completed for Strategy I.

EXHIBIT XVII

NATIONAL WATERWAYS STUDY

SUMMARY OF ACTIONS FOR STRATEGY II

	Scenario(1)			
	Base-Line	High Use	Low Use	Bad Energy
1. Completion of Present System	X	X	X	X
2. Normal Operations and Maintenance				
A, B, Major Ports	X	X	X	X
C				
Minor Ports and Side Channels				
3. Managerial Actions at Congested Locks	X	X	X	X
4. Channel Maintenance (Dredging)				
A, B, Major Ports	X	X	X	X
C				
Minor Ports and Side Channels				
5. Rehabilitation				
A, B, Major Ports	X	X	X	X
C				
6. Minor Safety Actions	X	X	X	X
7. Structural Actions at Locks				
PRIMARY CONSTRAINING LOCKS				
Mississippi Lock and Dam 26	X	X	X	X
Welland Canal (5 Locks)	X	X	X	X
Gallipolis	X	X	X	X
Demopolis		X		
Uniontown		X		X
Sault Ste. Marie				
SECONDARY CONSTRAINING LOCKS				
La Grange	X	X	X	X
Peoria	X			X
Marseilles	X	X	X	X
Mississippi Lock and Dam 22	X			
Oliver				
Warrior				
Holt				
Newburgh				
McAlpine				
Coffeeville				
Bankhead				
POTENTIALLY CONSTRAINING LOCKS				
Inner Harbor				
Montgomery				
Ohio Locks and Dam 52				
Bonneville				
TOTAL LOCK ACTIONS	11	11	9	11

X This class of actions taken.

Note: (1) No evaluation of high coal export or defense scenario was completed for Strategy II.

EXHIBIT XVIII

NATIONAL WATERWAYS STUDY

SUMMARY OF ACTIONS FOR STRATEGY III

	Scenario: Base-Line	High Use	Low Use	Bad Energy	High Coal Exports	Defense
1. Completion of Present System	X	X	X	X	X	X
2. Normal Operations and Maintenance						
A, B, Major Ports	X	X	X	X	X	X
C	X	X	X	X	X	X
Minor Ports and Side Channels	X	X	X	X	X	X
3. Managerial Actions at Congested Locks	X	X	X	X	X	X
4. Channel Maintenance (Dredging)						
A, B, Major Ports	X	X	X	X	X	X
C	X	X	X	X	X	X
Minor Ports and Side Channels	X	X	X	X	X	X
5. Rehabilitation						
A, B, Major Ports	X	X	X	X	X	X
C	X	X	X	X	X	X
6. Minor Safety Actions	X	X	X	X	X	X
7. Structural Actions at Locks						
PRIMARY CONSTRAINING LOCKS						
Mississippi Lock and Dam 26	X	X	X	X	X	X
Welland Canal (5 Locks)	X	X	X	X	X	X
Gallipolis	X	X	X	X	X	X
Demopolis	X	X	X	X	X	X
Uniontown		X		X	X	X
Sault Ste. Marie		X			X	X
SECONDARY CONSTRAINING LOCKS						
La Grange	X	X	X	X	X	X
Peoria	X	X	X	X	X	X
Marseilles	X	[illegible]	X	X	X	X
Mississippi Lock and Dam 22	X	X		X	X	X
Oliver	X	X	X	X	X	X
Warrior		X			X	X
Holt		X			X	X
Newburgh				X	X	
McAlpine		X			X	X
Coffeeville		X			X	X
Bankhead					X	
POTENTIALLY CONSTRAINING LOCKS						
Inner Harbor		X			X	X
Montgomery		X		X	X	X
Ohio Locks and Dam 52						
Bonneville						
TOTAL LOCK ACTIONS	13	21	12	16	24(1)	21

X This class of actions taken.

Note: (1) Total also includes an action at Kentucky Lock.

NATIONAL WATERWAYS STUDY

SUMMARY OF ACTIONS FOR STRATEGY IV

	Scenario					
	Base-Line	High Use	Low Use	Bad Energy	High Coal Exports	Defense
1. Completion of Present System	X	X	X	X	X	X
2. Normal Operations and Maintenance						
A, B, Major Ports	X	X	X	X	X	X
C	X	X	X	X	X	X
Minor Ports and Side Channels	X	X	X	X	X	X
3. Managerial Actions at Congested Locks	X	X	X	X	X	X
4. Channel Maintenance (Dredging)						
A, B, Major Ports	X	X	X	X	X	X
C	X	X	X	X	X	X
Minor Ports and Side Channels	X	X	X	X	X	X
5. Rehabilitation						
A, B, Major Ports	X	X	X	X	X	X
C	X	X	X	X	X	X
6. Minor Safety Actions	X	X	X	X	X	X
7. Structural Actions at Locks						
PRIMARY CONSTRAINING LOCKS						
Mississippi Lock and Dam 26	X	X	X	X	X	X
Welland Canal (5 Locks)	X	X	X	X	X	X
Gallipolis	X	X	(1)	(1)	X	X
Demopolis	X	X	X	X	X	X
Uniontown	X	X	(1)	X	X	X
Sault Ste. Marie	X	X	X	X	X	X
SECONDARY CONSTRAINING LOCKS						
La Grange	X	X	X	X	X	X
Peoria	X	X	X	X	X	X
Marseilles	X	X	X	X	X	X
Mississippi Lock and Dam 22	X	X	X	X	X	X
Oliver	X	X	X	X	X	X
Warrior		X	X	X	X	X
Holt		X	(1)	X	X	X
Newburgh	(1)	(1)		(1)	(1)	(1)
McAlpine	X	X	X	X	X	X
Coffeeville		X			X	X
Bankhead					X	
POTENTIALLY CONSTRAINING LOCKS						
Inner Harbor	X	X	X	X	X	X
Montgomery		(1)		(1)	(1)	(1)
Ohio Locks and Dam 52	X	X	X	X	X	X
Bonneville	X	X	X	X	X	X
TOTAL LOCK ACTIONS	40(3)	44(4)	38(5)	42(4)	46(6)	44(4)

X This class of actions taken.

Notes: (1) Capacity is added by the effect of deepening and no other action is taken at this lock.
(2) Totals include structural actions taken at other locks which are not constraining. These actions are taken either to accommodate deeper channels, to address obsolescence, or to reduce congestion. See the NWS report, entitled "Evaluation of Alternative Future Strategies for Action" for additional detail.
(3) Total includes actions at 21 other locks.
(4) Total includes actions at 22 other locks.
(5) Total includes actions at 19 other locks.
(6) Total includes actions at 23 other locks.

NATIONAL WATERWAYS STUDY

SUMMARY OF ACTIONS FOR STRATEGY IV (Cont'd.)

All of the following actions would be taken by Strategy IV for all scenarios.

8. Major safety actions substituted for minor safety actions at various sites as shown in the table below.

Major Structural and Other Major Actions To Enhance Safety

Region	Bridge Removals	Bridge Alterations	Bridge Replacements	Rock Cuts
Upper Mississippi River	2	2	-	1
Lower Mississippi River:				
Baton Rouge to Gulf	-	1	-	-
Illinois Waterway	4	-	2	2
Ohio River	1	1	-	-
Tennessee River	1	1	-	-
Gulf Coast West	-	3	-	-
Washington/Oregon Coast	1	-	-	-
Other Regions	-	-	-	-
Total	9	8	2	3

9. Deferred maintenance dredging is undertaken.

10. The following shallow draft channels are deepened:

River	Depth
Mississippi River from Cairo to mouth of Illinois River	12'
Illinois Waterway	12'
Ohio River from confluence of Allegheny and Monongahela to mouth	12'
Mississippi River from mouth of Illinois to Pool (vicinity of Dubuque, Iowa)	10'

11. The Tombigbee River would be widened to accommodate 8 barge tows from the mouth of the Black Warrior River to the confluence of the Tombigbee with the Alabama River.

12. The deep water coastal ports of Galveston, New Orleans, Baton Rouge, Mobile, Norfolk, and Baltimore would be deepened to 50' or more.

13. Obsolete locks would be replaced or modified at 10 sites.

END

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